SOIL CONSERVATION

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A Challenging Field for Research

By James T. Jardine[1]

RECENTLY public attention has been called forcefully to the wastage of our soils through erosion. It may be surprising to some of us that so little thought was given to this problem in the past; yet it is not so surprising when we realize that this is a relatively new country in which land, for the most part, has been both abundant and cheap. In the exploitation of soils and the subsequent endeavor to redeem them, we are merely repeating history. Perhaps we of this country are somewhat exceptional, however, in that we are beginning in time to save our soils and are invoking the forces of science to help us.

The Division of Research of the Service is fortunate indeed that it does not have to begin its studies from "scratch," as the Department of Agriculture and the State stations had to do some 50 years ago. Since that time, the sciences have become effective tools for the solution of agricultural problems, and satisfactory forms of research organization and administrative policy have been evolved. By the application of the sciences in State and Federal research agencies, much has already been learned about soils and their utilization in crop and livestock production. While earlier research may not have been specifically designed to solve the problems of erosion control, much of it throws light upon the problems involved. These studies have yielded valuable information concerning the nature of soils, soil fertility, plant foods, plant food requirements, and the entire matter of crop and livestock farming.

The task before the research workers therefore is simplified by the research that has gone before. Their commission is to plan and conduct new research especially designed to develop erosion control practices and in so doing to coordinate their efforts with the other research agencies, State and Federal, the work of which has much to contribute to the solution of erosion control problems. The soil conservation research specialists thus become analysts and synthesists of research efforts and results in many fields and subfields. For example, 10 years' results from a dozen soil erosion experiment stations, combined with the physical and biological knowledge already accrued for agriculture, gave the Soil Conservation Service a preliminary basis for its operations and extension activities.

The cooperative relations established by the Soil Conservation Service with other Federal agencies and the State Agricultural Experiment Stations thus become obviously a most effective means of attaining the objectives of the Research Division. Through such relationships, the research forces of the Service will have available the benefits of practically all the agricultural research talent of the country.

Soil conservation research specialists are challenged therefore; and the answer to the challenge calls for the visualization of the more outstanding problems to be found in the field and the capacity to enlist the services of both State and Federal research agencies in a broad effort to discover and assemble a body of knowledge adequate to the control of erosion as it bears upon the conservation of soils and soil fertility.

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Research In Soil Conservation

By W. C Lowdermilk [1]

PHYSICALLY, land use is conditioned essentially by three major factors, namely, (*a*) needs of plant and animal products, (*b*) soil productivity, and (*c*) integrity of the soil resource.

The need for food and other products rises with advance in social development from a subsistence requirement to levels of economic demand. But economic demands, throughout such development, are relative in place and time. The satisfaction of the primary demand for food becomes in modern society a commercial objective for supplying an economic want. The continued satisfaction of wants, whether subsistence or commercial, is conditioned, moreover, by the other two factors of land use.

In the second place, land use responds to the relative and absolute productive capacity of soils. Under natural conditions the store of plant nutrients is main-

Extremes in land use are represented in the three pictures on these two pages.

The aerial view above is of a Southern farm entirely shorn of its productive capacity—a scene of utter ruin and desolation resulting from an exploitative system.

Opposite, at the right, is bench terracing on mountain slopes in Peru. Built long before Columbus discovered America, still extensively in use, this terracing represents an original investment of human labor equivalent to $18,000 to $35,000 per acre and is indicative of the lengths to which a people will go to survive.

The third picture, taken in Wisconsin, represents a logical and constructive transitional stage between an exploitative and a permanent agriculture. It shows practices designed to reduce soil wastage which are less elaborate but economically justified under conditions prevailing in many parts of the United States.

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tained, at least approximately, by the balancing of losses through leaching with increments. Such increments in the natural state occur in dust, rainfall, in the decomposition of plant debris, in the release of nutrients through weathering of fresh soil material and rock, in overwash, and in the fixation of nitrogen by bacteria. Under use, however, certain critical elements such as nitrogen, phosphorus, potassium, and calcium are removed in harvested crops. Soil management under otherwise favorable conditions becomes a simple business transaction whereby the differential in removal of nutrients is replenished by leguminous crops and by commercial fertilizers. Yet this transaction of the soil cannot last long unless the physical body of the soil resource is maintained.

The integrity of the soil resource is the third basic factor of land use. Until recent years it has been too much overlooked. Maintenance of physical integrity

of the soil resource accordingly requires special attention and investigation; it is fundamental in the conservation and sustained utility of the soil and waters of the land. Such maintenance rests upon an accurate diagnosis of the effects of present land use from problem area to problem area and the discovery of safe limits in uses of land.

Not only does the physical integrity of the soil hold the fate of agricultural production, but it holds as well the fate of the distribution of precipitation waters and the production and accumulation of erosional debris. The destruction of the physical body of the soil resource sets in motion a train of events, social, economic, and physical, which affects not only agricultural production but flood flows and the utility of water resources.

Upon this three-footed base land use would appear to rest. All factors are interrelated, but safeguarding the physical integrity of the resource with its direct and indirect influences becomes a primary requisite in long-range conservation of land resources.

Function of Research

Research in soil conservation involving causes and control of erosion must begin with the soil resource, including the normal processes of its formation and removal and its interrelations with plant and water resources. It must, thereupon, explore the nature, causes, extent and effects of soil and water wastage under necessary agricultural pursuits. It must determine and test fundamental, practical and economically feasible means of conserving the resource by preventing undue wastage and by restoration of these resources incident to needful and sustained land use. It must bring to bear upon the problems involved several fields of science and practice and call into effective cooperation the agencies concerned with these special fields; it must develop in cooperation with State agricultural experiment stations a forward-looking program of needed basic and applied research by States and problem areas. It must plan and carry out in cooperation with State agricultural experiment stations and other appropriate scientific and technical agencies, essential projects of basic and applied research. It must take part in fitting the findings of research to the land in accord with its needs and adaptabilities on operations projects as proving grounds, in cooperation with field and technical organizations. It must further provide, in cooperation with State agencies, for adequate basic and applied research on the effects of land use on water resources, stream flow, and flood flows as influenced by rates and amounts of storm run-off, by detention storage, and by the accumulation of erosional debris. It must determine, in collaboration with appropriate agencies, the economics of erosion and of its control from the viewpoint of the farmer as well as from that of the community and the public.

In fulfilling these functions, research must serve the present and future needs of farmers and of land-use agencies and contribute to the planning for sustained land use by furnishing the specialists of the Soil Conservation Service engaged in work on the land, and other agencies, tested and reliable information on, as well as criteria for, measures and practices of soil and water conservation. The research function embodies the role of the prophet.

Correlation of Functions

Research in soil conservation is organized to conduct basic investigations responsive to the needs of science and practice. It is conducted as a cooperative enterprise with State agricultural experiment stations as State headquarters and in field stations as centers of work for problem areas. Investigations include (*a*) exploratory studies, (*b*) basic reasearch, and (*c*) field tests. Exploratory studies serve to evaluate going measures and practices and to point up questions which require answer and problems awaiting solution. In some cases field studies may suffice to yield satisfactory empirical answers ready for immediate application. In any case, they point up the questions or problems to be referred to soil conservation research laboratories or field stations for thorough study. Such basic investigations at cooperative field stations and laboratories will be carried as far as necessary in fundamental research to reach satisfactory solutions. In turn, the findings of research are applied in field tests cooperatively on field projects and conservation districts or other areas so as to fit the findings to the land, problem area by problem area. Such correlation of the functions of research and work on the land in the field laboratories and project areas assures reponsiveness to the needs of field practice as well as to requirements of scientific investigations.

Since erosion, together with the processes which it releases, is a complex phenomenon, its character and trends must be fully identified. As a geologic process, erosion is older than sedimentary rocks; it has sculptured landscapes and supplied materials for vast sedimentary deposits. Yet within regions enjoying a climate that supports a complete coverage of vegetation, this geologic erosion has not normally gone on faster than soil formation. Under such conditions, soils and natural vegetation have developed inter-

dependently through thousands of years. On the other hand, when the natural coverage of vegetation is removed by whatever cause, soils are bared, as never before, to the direct action of wind and flowing water. Erosion of an entirely different order, man-induced and accelerated, is thus introduced by agricultural operations. This soil erosion proceeds generally faster than soil formation, and unless controlled and prevented, condemns the soil to less productive uses or to serious depletion. Accordingly, the causes, character, and prevention of soil wastage by erosion, under necessary use for crops and livestock, and resultant disturbance in the regimens of water run-off, are conditioned by a complexity of environmental factors. Research in soil and water conservation consists in the analysis and synthesis of a number of fields of science in the interests of the farmer and agriculture. It must provide for meeting the hazards of use, but also for improvement of production under use, and for the restoration of depleted soils. Employing as it does specialists in a variety of fields, and involving several methods, research in soil and water conservation raises a challenge in coordination and synthesis which the Division of Research has accepted. The six sections of the Division are set up to divide the field systematically and to cover it adequately.

Organization of Division

To provide for adequate direction of the various phases of soil conservation research, and to give latitude and initiative to outstanding specialists, the Division is organized into six sections, each having a well-defined subject-matter responsibility and headed by specialists in their respective fields. The work of the sections is coordinated within the Division and correlated with the land action programs of the Service, and with scientific bureaus and other agencies. A brief description of the field of each section follows:

1. Investigations of the Principles Involved in Soil and Moisture Conservation and Methods for Their Practical Application on Agricultural Lands [2]

The object of the work under this section is to discover, to develop, and to test principles, measures, and practices in the agricultural uses of land which are necessary to conserve the integrity of the soil resource. The investigations include the development of effective and economical methods and practices for conserving soil and water under actual farming conditions. This calls for the testing of combinations and integrations of erosion control measures in different climatic regions with varied soils and sites, thereby determining the relative effectiveness and practicability on the farm of different practices or combination of practices. Field stations and State experiment station laboratories serve as centers of work for represented problem areas.

[2] See Field Research Offers Significant New Findings, by G. W. Musgrave. P. 210.

2. Watershed Investigations of the Effect of Land-Use Practices on Run-Off as Related to the Methods of Control of Erosion and Floods [3]

The objects of investigations under this section are to provide for the evaluation of the influences of land-use practices on storm run-off, stream flow, soil loss, and flood flow as affected by topography, shape, and size of drainage area, vegetative cover, surface and underground storage, tillage methods, and various erosion control practices, and to furnish information for the economic design of more effective erosion and flood control structures. Field stations and laboratories serve as centers of investigations for areas of similar hydrological characteristics.

3. Investigations of Sedimentation Resulting from Erosion [4]

The objects of investigations under this section are to furnish information on the damage done by accumulations of erosional debris and by sediments as well as the magnitude of potential damage to be expected if present land-use practices continue; to provide a measure of the relative needs of the different watersheds for erosion-control and readjustments in land use from the standpoint of protecting developed water storage, flood control improvements, and investments in agricultural land subject to damage from overwash of debris. Surveys and special laboratories serve for investigations on silting and the dynamics of silt-laden waters.

4. Investigations of Geographic and Climatic Factors Related to Erosion [5]

The object of investigations under this section provides for the determination and evaluation of the climatic factors causing regional differences in erosion and the interrelation of these factors with plant associations, topography, soil, and rock materials as they affect soil and water conservation practices; involving erosion history, the influence of erosion on ecologic changes of plant cover, physiographic research of

[3] See Hydrologic Investigations on Selected Watersheds, by C. E. Ramser. P. 215.
[4] See Relation of Sedimentation Studies to a Flood-Control Program, by G. C. Dobson. P. 219.
[5] See Recent Achievements of the Section of Climatic and Physiographic Research, by C. W. Thornthwaite. P. 226.

normal geologic erosion under various climates and topography and soil, and climatic research as it affects erosional processes. Field studies and surveys serve to supply data for laboratory and office analysis and reports.

5. Investigations of Erosion-Resisting Plants of Economic Value [6]

The object of investigations under this section is to find, test, improve, and develop economical methods of reproducing and utilizing specialized vegetative plants that are profitable in preventing soil erosion in different climatic regions. This provides for the development of a new supplemental system of permanent and profitable erosion-control farming and soil conservation practices in the United States applicable to sloping or erodible areas in which ordinary types of agriculture or reversion to natural vegetative cover are neither practical from a soil conservation standpoint nor profitable from the viewpoint of the landowner. Nurseries, field stations, and State agricultural experiment stations serve as the centers for hillculture investigations and tests.

6. Cooperative Investigations of Economics of Soil Erosion and Erosion Control [7]

The object of investigations under this section is to determine the economic effects of soil erosion and of soil conservation measures upon farm business and farm income and, furthermore, upon the community and social benefits as a basis for determining the distribution of the burden of soil and water conservation measures. These studies are conducted in cooperation with the Bureau of Agricultural Economics and economists at State agricultural experiment stations and projects of the Service.

The field organization includes all personnel of the Division engaged cooperatively with State agricultural experiment stations and other scientific and technical agencies and with field operations of the Soil Conservation Service, in formulating research programs and projects and in carrying out exploratory studies, research projects, and field tests in accordance with approved plans and projects.

The work of the Division is based upon a series of exploratory studies, research projects, and field tests dealing with specific problems which are being fitted into a forward-looking and integrated program of research. The research projects now in progress within a State, together with those subsequently developed, constitute a State program of soil conservation research. The State programs together with studies established in consultation with the National Research Council and other agencies in turn become a national program of research in soil and water conservation.

[6] See The Soil-Saving Persimmon, by S. B. Detwiler. P. 230.

[7] See Economic Implications of a Soil and Water Conservation Program, by Walter J. Roth and Alexis N. Garin. P. 223.

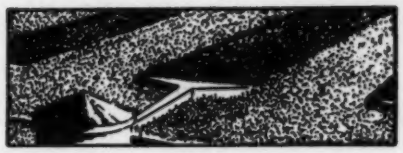
Preparing a State Program

In accord with the Memorandum of Understanding between the several States and the Soil Conservation Service, all research undertaken within a State by the Service will be in cooperation with the State agricultural experiment stations. Thus, the State becomes the unit in the formulation of the research program which must serve not only the immediate needs of the erosion control activities of the Service but also the agriculture of the State, of the problem areas which extend beyond State boundaries, and of the Nation as a whole. The work of the Division of Research is therefore a cooperative enterprise with the several States participating through their respective experiment stations and other research institutions.

The procedure for setting up programs of research necessarily must vary somewhat from State to State, but in every case three steps are involved. The first step is a study of the soil and moisture conservation problems of the State, the second a survey of the research work now in progress, and, third, the programming of the research necessary to meet the needs of a sustained land-use program. A schedule of needed research projects arranged in order of their importance will serve as a guide for the development of detailed work projects and the assignment of personnel. The rate at which the work can be undertaken will be determined by the funds available to the cooperating agencies and by the available personnel and facilities.

In the following pages are set forth some of the activities of workers of the Division of Research. These papers may serve to give some idea of the nature and scope of integrated investigations in the vital problems of land use and principles of the conservation of the soil, of conditions of soil productivity, and of utility of water resources which arise from the falling of rain and snow upon farm fields, pastures, wooded lands, and forests. The fate of a farm and the welfare of the farmer is tied up in the fate of the raindrops that fall upon his fields; in very truth the destiny of a civilization is inseparably linked with the fate of drops of rain and grains of soil under the action of wind and water.

Size and Shape of Control Plots for Run-off Studies



By A. E. Brandt [1]

AN OLD problem in a new guise is now being faced by all research agencies using control plots to study run-off and soil loss either induced by the application of water to simulate rain or as a consequence of natural rains.

It is generally agreed that the results obtained from field experiments with most plants may be influenced considerably by border effects. These border effects may be harmful in that the parts above ground compete for sunlight and those parts below ground for nutrients and water; or, on the other hand, they may be beneficial in providing protection from hot winds. The harmful effects can be eliminated by harvesting the crop or by making the necessary observations in such a manner as to exclude from the experimental results the observations on the borders. The portion of a field plot to be considered as border depends, among other things, on the height and density of growth above ground and the type of root system; but, as a rule, this must be determined by experimentation.

In control plot investigations as now carried on by the Soil Conservation Service it is not possible to measure the run-off and soil loss from various portions of the width and discard the information for the border portions. In order that the water which runs off the surface of an experimental plot may be conducted to proper catchment basins or tanks for measuring and for determining the load of earth carried, side baffles of earth or other material such as metal must be provided. Evidence obtained from control plots now in operation leads one to believe that as the water runs down the slope there is undue concentration along the baffles which modifies the erosion pattern. It is possible that, in addition to affecting the erosion pattern, this concentration of water along the borders influences the loss of soil and water from the plot.

It is the general opinion, where the treatments or factors being investigated by means of control plots are such that the plots throughout the experiment are all of the same size and shape, that the border effect does not introduce a bias which will lead the investigator to conclude that treatment A is superior to treatment B when, in fact, the opposite is true. However, when factors such as grade and spacing, which are important in the design of terraces and strip cropping layouts, are being investigated by means of control plots, the plots will of necessity differ in size in the same experiment.

The importance of the effect of the concentration of water in the border areas relative to the remaining area of the plot may, quite obviously, be reduced as much as desired by increasing the width of the plot. There are, however, certain factors in addition to border effects which must be considered when selecting the size and shape of plot to be used in an experiment, such as present knowledge concerning the subject being investigated, nature of the crop to be grown, purpose of the experiment, available facilities, and certain practical limitations.

On the basis of the present knowledge concerning the subject being investigated three classes of field experiment may be pointed out: preliminary or pilot experiments, critical experiments, and demonstration experiments. When a new line of investigation is opened up, a number of exploratory or pilot experiments are usually set up to find leads which will point the way for further and perhaps more precise study. In this preliminary or exploratory stage, as a general rule, only large differences are considered and large plots may be used and, in some instances, even replication is dispensed with, since the degree of precision need not be very high. In further following a lead provided by a preliminary experiment, smaller differences due to experimentally controlled variations of one or more factors will be encountered and more efficient plots must be selected to provide critical comparisons of one or more criteria. When a principle has been established by adequate experimentation, demonstration or extension experiments are sometimes set up to assist in spreading information regarding this principle. Since such experiments are arranged for exhibition, the experimentally controlled factors rarely ever are assigned to the plots at random and are seldom replicated.

Precise tests of significance are yielded only by critical experiments in which the experimental variants are properly randomized and replicated, but data from either of the other two kinds are frequently treated by statistical methods applicable to data from critical experiments only. It is seldom that the results of exploratory experiments are sufficiently precise to

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serve as a valid basis for drawing definite conclusions except between widely differing treatments or practices. Strictly speaking, demonstration experiments are not experiments at all but oversimplified exhibits of experimentally established principles. Accidents of location, season, and various uncontrollable factors in demonstration experiments lacking proper randomization and replication may produce startling apparent differences and lead to erroneous conclusions. With a little explanation a properly designed critical experiment will serve very well for demonstration purposes and will not be as likely to mislead the casual observer.

The nature of the crop to be grown on an experimental area must be carefully weighed when an experiment is designed. Obviously a forest or orchard crop will call for larger plots than a close growing crop. Of the closer-growing crops, one grown in rows such as sugar beets, corn, or cotton, may require larger plots than small grains or grasses. Height of mature plant, rate of growth, susceptibility to shade, and type of root system are other natural variations which affect size of plot.

In a Greco-Latin square (see front cover) there are two types of cross hatching (parallel to the sides of the squares and diagonal) and three kinds of each type used in this. The conditions for forming a Greco-Latin square require that one kind of each type shall occur once but only once in each row and in each column and that each kind of one type shall occur in a plot with each kind of the other type once but only once in the entire square.

The last two named factors—available facilities and practical limitations—are so closely related that one might combine them. Of the facilities that might be limited, money, land, seed, and help might be mentioned. Experiments involving different methods of preparing the seedbed, of seeding or of cultivating the growing crop, may call for machines which will in a practical way determine the size of plot. The half-drill strip is an example.

For critical experiments, two types of design have proved to be efficacious. These are the Latin square and the randomized block. In the Latin square the plots should be as nearly square as possible, while in the randomized block design they should be long and narrow with the blocks as nearly square as possible. Since much of the experimentation in run-off and soil loss studies must be conducted on plots greater in one dimension, the Latin square design will seldom be used. It has been demonstrated through the utilization of data from uniformity trials, that plots should be as small as is possibly consistent with the factors discussed above. Smaller plots generally yield more information per unit area and are therefore said to be more effective.

Field Research Offers Significant New Findings

By G. W. Musgrave [1]

THE Section of Soil and Water Conservation Experiment Stations carries on its investigational program through field experiment stations located in various problem areas of the country, which are determined by prevailing soil types, weather conditions, topography, and agricultural practices. These field stations are cooperative with State agricultural experiment stations and serve as centers of investigations in erosion control and soil and water conservation for the problem areas represented.

At these field stations the nature and relationship of the basic factors affecting soil erosion are subjected to rigorous investigation. Measurements are made of the quantities of run-off and soil loss occurring under various field conditions for the purpose of determining the effects of these conditions on soil erosion and gully formation, and methods and devices for the control of erosion are developed.

A brief discussion of some of the more recent outstanding results of the work of the section follows:

Close Vegetation Reduces Rate of Run-off

A recent analysis of hydrographs made at the Clarinda and Bethany experiment stations, of run-offs from 50 storms of high intensity, shows that the average maximum rate of run-off from cornland on an 8-percent slope was two and one-half times greater than that from similar areas in clover and timothy. The extent of the effect of such close vegetation as bluegrass, Bermuda grass, alfalfa, and clover in reducing soil and water loss has been well established by research workers in soil conservation, but the extent of the effect of close vegetal cover upon rate of run-off is largely unknown. The effectiveness of vegetal cover

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in reducing rate of run-off has a very definite bearing upon the kind of control measures that should be used under certain conditions, as the successful use of strip cropping, terracing, contouring, and similar measures are dependent partly upon the rate of flow of run-off. The problem is important, furthermore, because of the fact that a retardation in rate of run-off is accompanied by far more than a proportionate reduction in amount of erosion.

The data included in the study reported cover the records of 3 years at one station and 5 years at the other under a wide range of rainfall and cover-crop conditions. During this entire period the only exception to the general result was from a storm producing run-off immediately after the plowing of corn ground. In this instance measurements showed that the plowing had loosened and fluffed up the soil to such an extent that the average land level was raised 2.4 inches. This provided additional pore space and probably accounted for the greater infiltration of water on the freshly plowed land than on the settled soil with close vegetal cover.

On Shelby loam, where the average amount of run-off from cornland from the 50 most intensive storms was 0.57 inch, the average rate of run-off was 0.67 inch an hour, or 2.5 times greater than the run-off from similar areas in clover and timothy. On this soil 24 of the 50 rains occurred during 3 years of a 5-year period. All 24 rains were relatively severe, but they were well scattered. For these rains the average maximum rate of run-off from corn was 0.91 inch an hour, or two and one-half times greater than that from clover and timothy, despite the fact that the hay crop was poor and averaged only 0.67 ton an acre. In general, similar results occurred on the Marshall silt loam. On both Shelby and Marshall soil the effect of vegetal cover in preventing run-off was demonstrated even when the soil was saturated

At left: A strip channel lined with Bermuda grass being tested at the Spartanburg outdoor hydraulic laboratory.

Below: This dam, built at the head of a rapid, creates a reservoir for the laboratory. The hillside downstream provides a good opportunity for experimental work.

with water and the amount of run-off from different kinds of covers was nearly the same. These results, developed by some of the most careful studies thus far conducted, indicate but one of the reasons why dense vegetation should be used wherever practicable.

Crops with Large, Dense Foliage Intercept Rainfall

Crops with large, dense foliage not only protect land from the force of beating rains but also intercept an appreciable amount of water with their leaves and stems. These effects were found in preliminary studies conducted at the Clarinda, Iowa, station in 1935, and were later enlarged upon in a carefully organized investigation requiring the development of special types of measuring equipment. The investigations included records from alfalfa, oats, corn, and soybeans throughout the growing season and from timothy, bluegrass, and wheat during part of the growing season. Intensity recorders were used so that not only the total amount of water reaching the surface of the ground beneath the canopy of a crop was measured but also the rate of fall. The figures obtained were compared with the amount and rate of rainfall that reached the surface of ground in the open. Devices were constructed so that the amount of water moving down the stems of some of the plants was measured separately from the amount that penetrated the canopy.

The studies showed that the interception of rainfall by the canopy of crops increases as the crops approach maturity, and that there is a direct increase in interception with increase in vegetative cover. For the rains which occurred in the 1937 season at Bethany, Mo., oats intercepted 7.2 percent of the total rainfall, soybeans 12.4 percent, corn 12.7 percent, and alfalfa 35.7 percent. The percentage of interception, of course, varies greatly with the intensity of the storms, and the figures cited for the 1937 season undoubtedly would differ for other seasons or other rainfall amounts, but they serve to indicate the wide differences which occur for different kinds of crops. During the month previous to their respective harvests, wheat intercepted 19 percent of the rain which occurred during the period, timothy 26 percent, and bluegrass 17 percent. The distribution of rainfall under the plants indicated that they tend to shed water toward their outer margins. It was found also that more rainfall reaches the ground on the windward side than on the leeward side of isolated plants. It was found furthermore that drilled crops tend to concentrate water in the spaces between rows. Thus, the study indicated that vigorous, well-nourished plants offer greater protection to land than plants of the same kind that are not thriving well; that the spacing of plants may have much to do with the degree of protection they provide; and that certain species, for example, alfalfa, are much more protective than others.

Organic Matter Increases the Permeability of Most Soils to Water

It is a matter of common observation that organic matter improves the physical condition of soil and promotes plant growth, but very few quantitative data are available on its effect on erodibility. Field and laboratory studies have therefore been conducted recently to determine the effect of organic matter on the erodibility of soil.

Samples of surface soil and subsoil from representative plots of the Dekalb, Upshur, Hagerstown, and Monongahela soils were given different organic-matter and lime treatments. A part of each sample was maintained under field conditions, while the other part was kept in the laboratory under optimum conditions of moisture and temperature. Determinations of the dispersion ratio and aggregate distribution of the samples were made 1, 3, and 5 months after treatment. Determinations of infiltration rate, organic-matter content, moisture equivalent, and volume weight and mechanical analyses were made at the end of the 5-month period.

Under field conditions there was a very significant increase in the rate of movement of water through the soil 6 months after treatment with organic matter. The average infiltration rates, in inches per hour, of the soils that had not been treated, as measured over a 2½-hour period following 48 hours after an initial 2½-hour run, were as follows:

Soil:	*Infiltration rate in inches per hour*
Dekalb surface soil	0.87
Dekalb subsoil	.90
Hagerstown surface soil	.91
Upshur surface soil	1.74
Monongahela surface soil	2.06

The infiltration rates of the same soils that had been treated with organic matter were:

Soil:	*Infiltration rate in inches per hour*
Dekalb surface soil	3.94
Dekalb subsoil	3.97
Hagerstown surface soil	1.89
Upshur surface soil	2.95
Monongahela surface soil	4.67

In the laboratory packed samples, which had a higher apparent specific gravity than the field samples, or-

ganic matter increased the rate of water movement very significantly in all soils except the Upshur surface soil and subsoil. Lime increased the rate of percolation in the Dekalb surface soil and subsoil, but caused a slight decrease in the Upshur surface soil and subsoil and in the Monongahela surface soil. Dekalb surface soil and subsoil treated with lime and organic matter together showed a very significant decrease in rate of percolation as compared with soil treated with organic matter alone, but a significant increase as compared with the untreated soil. The treatment of lime and organic matter in the Upshur surface soil and subsoil and in the Monongahela surface soil resulted in a rate of percolation slower than that of either the untreated soil or the soil treated with organic matter. The reasons for this decrease are not readily apparent, but the failure of organic matter to affect the water relationship and other physical properties of the Upshur soil was apparently due to the presence of a high percentage of active inorganic colloidal material. In all soils except the Upshur surface soil and subsoil there was a very significant decrease in the percentage of aggregates less than 0.05 mm in diameter, and an increase in the percentage of aggregates greater than 0.25 mm in diameter from applications of organic matter. The aggregating effect of organic matter was most evident in the silt loams low in active inorganic colloidal material and in organic matter.

The effect of organic matter on aggregate distribution and on dispersion ratio was practically the same 1 month and 5 months after treatment. It is indeed interesting that organic matter had so great an effect only 1 month after treatment. Whether or not any further effect on aggregate distribution by organic matter after further decomposition would be counteracted by increased dispersion because of higher temperatures and the drying of the soil is not definitely known. Organic matter decreased the apparent specific gravity because it lessened the weight per unit volume and caused aggregation of the finer soil fractions. The dispersion ratio was likewise decreased, but the moisture equivalent and the percentage of organic matter were increased.

With the samples collected from pasture plots located on Dekalb soils, fertilization had no significant effect on aggregate distribution or on dispersion ratio. The plots from which the samples were taken were located originally on old sod that was largely bare or covered with undesirable species. After 6 years the treated plots supported an excellent stand of bluegrass and white clover, whereas the untreated plots were still very poor. Grass seeded on intensively cultivated soil low in organic matter, however, would probably affect its physical condition favorably within a relatively short time. Comparison of the plots with adjoining pastures and cultivated fields on the same soil showed that cultivation had decreased the percentage of large stable aggregates very materially and increased the percentage of smaller sized aggregates. These data indicate that improving a poor pasture which has been in sod for many years may not materially change its physical condition.

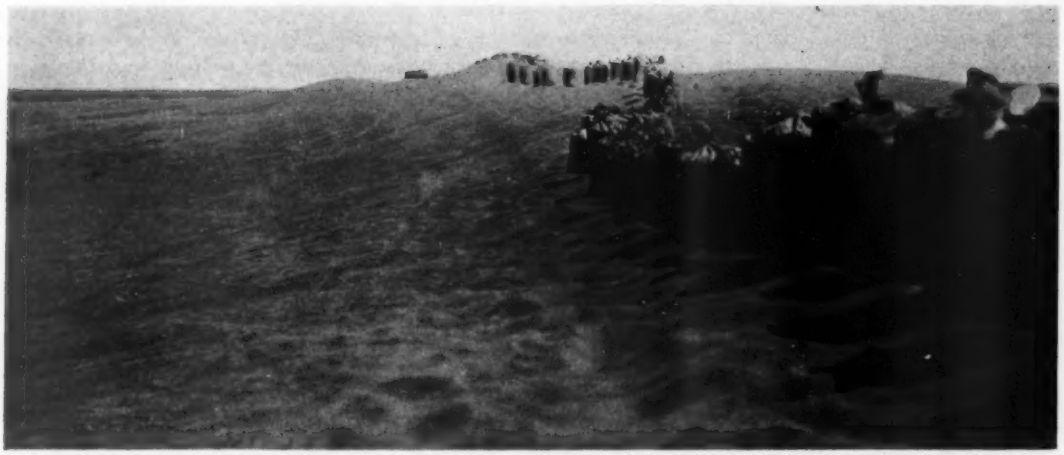
It is logical to assume that a treatment that decreases the ease with which soil is brought into suspension and thereby lessens run-off, that clogs the pores of the soil and thus prevents infiltration of water, and that increases the number of large stable aggregates, total and noncapillary porosity, size of capillary pores, and infiltration capacity, will aid in the conservation of soil and water. The indirect effects of organic matter in erosion control, through stimulation of plant growth and consequent interception of the force of rain, and through the action of roots and worms in bringing about favorable structural conditions, are also important.

Testing Structures for Use Upon Farmlands

The ability of various kinds of erosion-control structures to withstand storms of 10-, 25-, or 100-year frequency may now be determined without awaiting the occurrence of such storms. This has been made possible through the ingenuity of the hydraulic engineers of the Section of Soil and Water Conservation Experiment Stations. It is now possible to obtain within a short time data that otherwise might have been collected only during a long period of years.

The behavior of various types of erosion-control structures has been studied under field conditions at the experiment stations for a number of years. Vegetated outlet ditches, channels of various kinds, small check dams, drop inlets, and similar structures have been installed for the purpose of determining their relative merits in erosion control. Under normal rainfall conditions, however, the structures may not be subjected to all the conditions necessary to obtain information for the safe and economic design of hydraulic works.

A program has therefore been initiated whereby control structures may be tested under all possible conditions. The work is being carried on principally at the hydraulic laboratory near Spartanburg, S. C., which is a small outdoor reservoir so located that water may be drawn from it along the upper side of a long steeply sloping hillside that provides suitable sites for structures under test. In the photograph



Gunny-sacks placed on top of dunes as wind deflectors. During one wind this dune was lowered 2 feet by this means; during another, 1 foot.

may be seen the dam that creates the reservoir and the hillside upon which the experimental work is conducted. The water supply of this reservoir has recently been greatly augmented, and flows as high as 50 cubic feet per second are now available. It is therefore possible to create for purposes of experimentation such conditions as would occur during critical storms. The results of this laboratory work will be correlated and compared with results occurring under comparable natural conditions as they occur.

Results of the tests that have been made show that Bermuda grass channel linings are extremely resistant to high velocities of flow. For short periods of time they will withstand velocities up to 8 feet per second without any permanent harmful effects. The illustration shows a steep channel lined with Bermuda grass over which a flow amounting to 1 cubic foot per second is running. Tests of vegetation for meadow strips seem to indicate that a good stand of Sudan grass will withstand velocities of 5 feet per second without undue harm, providing it is subjected to such velocities infrequently and for short periods only. Preliminary results indicate that first-year common lespedeza is more satisfactory in the protection of meadow strips than first-year lespedeza sericea, but that it is not as resistant to erosion as Sudan grass.

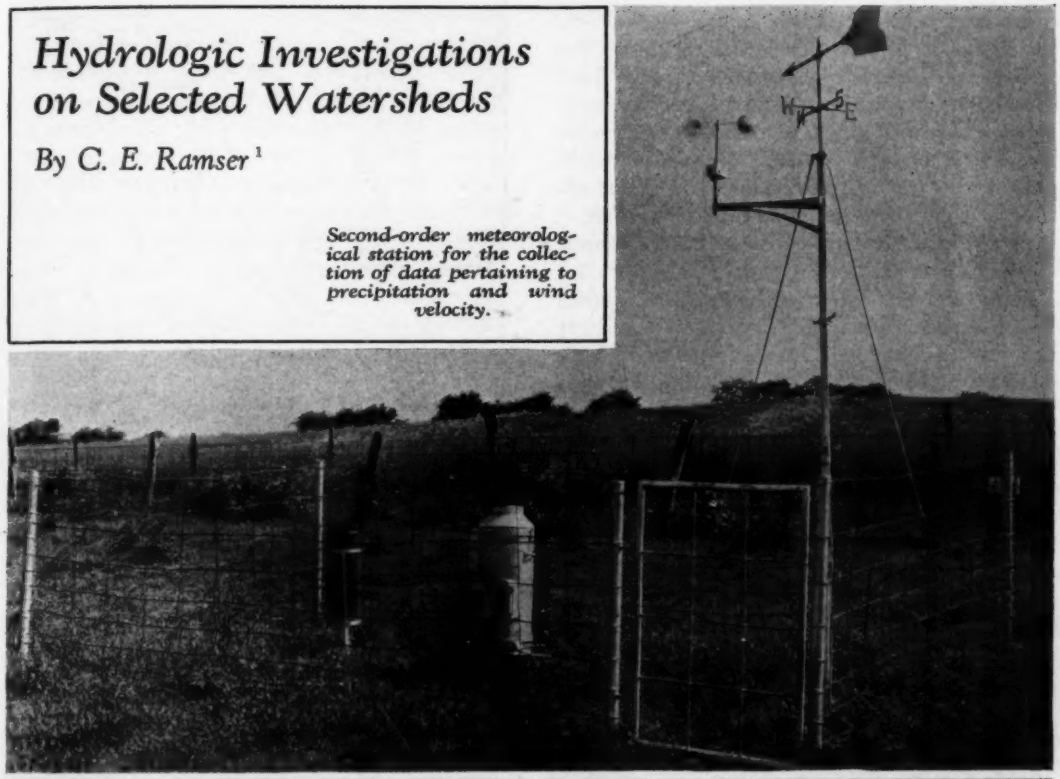
Studies of the water-carrying capacities of channels lined with vegetation showed that a notable reduction in velocity is brought about by vegetation. In shallow vegetated channels and meadow strips the value of Manning's n for depths of flow of about 6 inches was found to be about 0.05, whereas the corresponding value of Kutter's n is about 0.04. A full report on this significant study is being prepared for technical workers.

The new wind erosion station near Amarillo, Tex., has carried on a project in cooperation with the Division of Operations and the State experiment station to reclaim land that a year ago was a sand dune waste. This large area in the so-called "Dust Bowl" near Dalhart, Tex., had been so damaged by wind erosion in the blowing out and sorting of soils, with consequent formation of advancing sand dunes, that it was thought to have been virtually destroyed for further agricultural use. Furthermore, the advancing dunes were overwhelming good land lying in their paths. After a little more than a year of experimentation and application of research findings, splendid crops were produced upon this area. In the reclamation of mounting dunes the force of wind is utilized to level dune crests and redistribute the sand on the eroded land. The effect of wind jets was produced first by the setting on end of gunny sacks filled with sand at short intervals along the crests of dunes and then by gouging wind channels in the partially leveled dune areas. The spreading sand was caught in lister rows and stabilized by suitable vegetation. Measures were taken to conserve all available moisture within the tract. This work is described in more detail in the January issue of SOIL CONSERVATION.

As it relates to the Southern Great Plains area, this research project of sand dune reclamation, undertaken less than 2 years ago, is now completed. It has resulted in developing successful methods for reclaiming sand dunes, so that the methods may be prescribed and referred to the operations function of the Service for application on project areas.

Hydrologic Investigations on Selected Watersheds

By C. E. Ramser [1]



Second-order meteorological station for the collection of data pertaining to precipitation and wind velocity.

RESEARCH for available data needed in reporting on watersheds under the Omnibus Flood Control Act has disclosed a great lack of information relating to the influence of agricultural practices on water flow. This information is especially needed for carrying out those provisions of the act relating to the evaluation of land-use and soil conservation measures and practices in a national program of flood control. Under the act, the Department of Agriculture is called upon to report to Congress recommendations for measures and practices of land use and soil conservation which are justifiable in the interests of flood control and to supplement major engineering works in stream valleys.

Studies of the influences of land use on storm run-off, flood flows, silt production and water conservation are being conducted by the Section of Watershed and Hydrologic Studies. Such studies are planned to represent problem areas where soil and water conservation and flood control are inextricably related, and the problem areas will in time be located in a network of strategically placed experimental watersheds to serve as centers for land-use-hydrologic investigations. Thus far, three projects have been initiated, one within the Muskingum Conservancy District in Ohio, one within the Brazos River Reclamation and Conservation District in Texas, and one in the Central Great Plains.

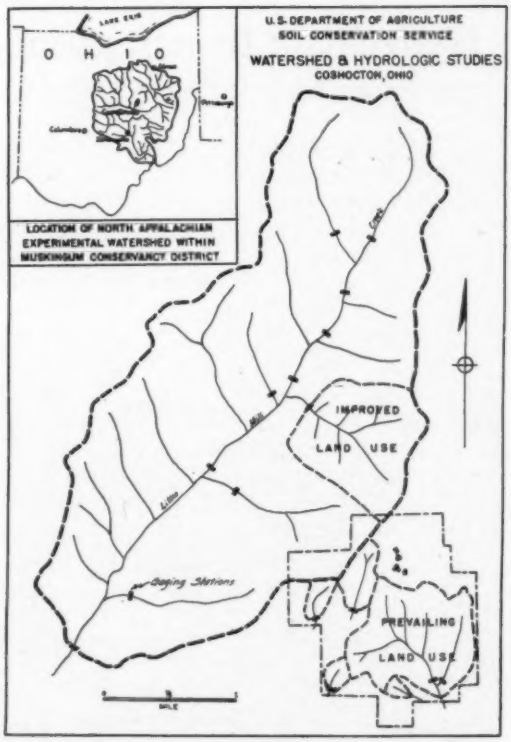
The Muskingum studies are being conducted in cooperation with the Ohio State Agricultural Experiment Station and the Muskingum Conservancy District. The Muskingum Conservancy District was formed for the purpose of providing protection against floods to the cities, towns, and farms lying in the valleys of the Muskingum River and its principal tributaries. With construction of flood-control reservoirs by the War Department and the Muskingum Conservancy District well along toward completion, it was particularly appropriate that the first project undertaken by this section should be representative of the North Appalachian hydrologic conditions and should lie in the heart of the Conservancy District. The district was quick to recognize the value of studies on the influences of land use on flood flows and silting, and the close cooperation is mutually advantageous.

[1] In charge, Section of Watershed and Hydrologic Studies, Division of Research, Soil Conservation Service, Washington, D. C.

The construction of 14 flood-control reservoirs by the United States Army Corps of Engineers for the Muskingum Conservancy District, at a cost of about $40,000,000, is nearing completion. The accompanying map of Muskingum Conservancy District shows the location of the reservoirs. Cooperative studies with the district have been initiated to extend the findings of the 5,000-acre experimental watershed to the 8,000-square mile watershed of the Muskingum Conservancy District.

All six sections of the Division of Research are taking an active part in the research work now under way and that contemplated, on the watershed of the Muskingum Conservancy District. The establishment of a network of self-recording precipitation stations, about 4 miles apart over the watershed of the Muskingum district, by the Section of Studies of Climatic and Physiographic Factors of Erosion, will furnish information relating to the storm pattern of all major storms over the watershed. This information will be indispensable in the study of routing flood flows, and of relations between peak stream discharges and intensities and amounts of rainfall over the watershed.

Measurements are made as well to determine the rate and amount of sedimentation in the reservoirs of the district for watersheds with controlled and uncontrolled land-use practices. Sedimentation measurements will be made in the reservoirs, at regular intervals, by the Section of Sedimentation Studies. The Division of Operations has established on the watershed of one of these reservoirs a project for the stabilization of the soil through improved land-use and soil conservation practices to be put into effect over the watershed draining into this reservoir.



In the preparation of a program for effective soil conservation practices to be employed over this watershed, the Division of Operations is guided by applicable experimental findings of the Section of Soil and Water Conservation Experiment Stations on the Soil Erosion Experiment Station at Zanesville, Ohio. The Section of Hill Culture Studies will work in cooperation with the Division of Operations, by employing certain shrubs and trees having a commercial value in the stabilization of the soil on certain areas owned by the Muskingum district. The district will also furnish information of general research value. Economic studies from the standpoint of land use, soil conservation, and flood control have been started by the Section of Investigation of the Economics of Soil and Water Conservation, on the 5,000-acre experimental watershed, and will be expanded to include studies in the Muskingum district relating especially to sedimentation of reservoirs and flood control.

These varied cooperative research activities will make the Muskingum Watershed Conservancy District the most complete flood control, land use, and soil conservation laboratory in the United States, if not in the world. No other research project has encompassed such a comprehensive program of research on a scale adequate to determine under reasonable control the influence of land use on storm run-off and flood flows. The findings of this undertaking will furnish reliable information on the influences of land use on flood control, silt control, and soil and water conservation, to serve as a guide in the planning, design, and financing of economic flood control projects in the future.

The first objective of the land-use-hydrologic studies is to furnish basic information necessary to a coordinated program of flood control for the safeguarding of agricultural lands and industrial and urban developments against flood damages. The Nation is committed to enormous expenditures for flood control; it is important that measures of flood control be complete and well coordinated, and take into account the factors which cause floods—from the fate of raindrops as they fall on the land until they have accumulated into raging flood flows in major streams.

In addition to problems of excess waters are those of insufficient waters. A knowledge of the influences of land use on water conservation, constituting the second objective, will furnish the basis for forward-looking land-use programs for the Great Plains drought area, as was reported to the President by the Great Plains Drought Area Committee. Crop losses experienced by farmers, not only in the semihumid but the humid regions of the United States during the past year, indicate the need for improved agricultural practices to conserve all available moisture for crops. Measures of erosion control tend to conserve moisture for crops, and it is essential that the effectiveness of these methods be ascertained in order to substantiate their adoption in a Nation-wide water conservation program. Also, a knowledge of the effect of land-use and soil conservation practices, on surface and under-

Strip-cropped field on the Coshocton experimental watershed project.

Foot bridge and cable station for making current meter measurements in open channels.

Typical watershed on Coshocton project, to be devoted to mixed land-use practices involving timber, pasture, meadow, and cultivated crops.

Parshall measuring flume and Ramser silt sampler used in measurement of run-off and soil loss from small watersheds.

ground water supplies for municipal, irrigation, and other purposes, is important in a program designed to work out the relation between these uses and the consumption of water by plants on watersheds. Such uses may in some instances be more or less conflicting. For example, surface water supplies for cities often command first consideration, calling on watershed management for maximum yields of water. On the other hand, land-use measures may reduce the water yield. Investigations are started in the Central Great Plains to determine what measures of land use can be recommended in the interests of sustained use of land and waters, to safeguard the soil as well as the utility of water resources.

The third primary objective of the land-use-hydrologic studies is to determine rates and amounts of run-off for the economic design of erosion-control structures and for related purposes. Run-off data are especially needed by operations projects of the Service. Run-off data are meager and inadequate for economic design for most erosion-control practices. For instance, the satisfactory design of notches for check dams, spillways, and drop inlet culverts, for soil-saving dams, channels, and outlet ditches for terraces, and diversion ditches for many different purposes—all of which are used in erosion control work—depend upon the availability of reliable run-off information from land areas. Structures may be underdesigned, resulting in failures, or overdesigned resulting in wasteful expenditures. Adequate run-off data should be used as the basis for all designs. The numerous failures, due to inadequate waterways for farm ponds, road bridges, culverts, and similar hydraulic structures are evidence of the lack of data on run-off.

Intensive studies designed to collect the foregoing information are being conducted on the watershed projects of this section. Detailed investigations are being made, on the experimental watershed projects, of the movement and action of water from the time it reaches the ground surface as precipitation until it leaves the watershed as surface or underground flow. These include studies of run-off and precipitation, percolation, and infiltration, evaporation, and transpiration, interception, surface, channel, and underground storage, and the movement of water over the ground surface and through stream channels. The part that these various factors play in the hydrologic cycle is graphically illustrated by the chart. Studies of precipitation relate to amount, intensity, duration, and areal distribution. A careful analysis is made of the physical characteristics of watersheds relating to soil and subsoil, topography, physiography, vegetative cover, geologic formations, and cultural factors, such as tillage and erosion-control practices.

The general plan of study includes: (1) the evaluation of all important factors by comprehensive experimental studies, and (2) tracing of the effect of these factors from small to large watersheds.

On the Coshocton, Ohio, experimental watershed project several batteries of in-place automatic recording water-cycle lysimeters have been built, to study the rate and amount relationships of rainfall, run-off, and percolation, and to evaluate evapo-transpirational losses.

Small watersheds of 1 to 10 acres will be used for experiments on the effect of erosion-control practices on the rates and amounts of run-off and soil erosion for rainfall of different amounts and intensities. Erosion-control practices to be used will depend upon their adaptability to the particular region. Some of these practices will be pasture, forest, cover and green manure crops, crop rotations, various tillage methods, strip cropping, and terracing.

Measurements of run-off and erosion on these small watersheds will be divided into two stages as follows: (1) For the purpose of determining the effect of inherent differences in the watersheds, due to influencing factors that cannot be readily evaluated, all the watersheds will be treated in a similar manner from the standpoint of cover. The duration of this stage will likely be 5 years or longer, depending on the normality of climatic and crop conditions during this period. (2) At the beginning of the second stage, the best erosion-control practices, as determined from the results of experiments at the soil-erosion experiment stations, will be established on a number of the small watersheds, and cropping and vegetative conditions on the other watersheds will continue, as during the first period, to integrate climatic conditions during the whole period of experimentation. The results of these experiments will give definite information on the effect of various erosion-control practices upon water conservation, storm and ground water run-off, and flood control. Many of these results will be indicated by trends that develop in the early years of the work.

Two rather similar watersheds of about 400 acres each have been selected on the Coshocton project for the purpose of conducting run-off and other investigations under present land-use practices. This will represent the first stage of the experimental studies. Afterward improved land-use and erosion-control methods will be put into practice on one of the watersheds, and the other of the two similar watersheds will

Relation of Sedimentation Studies To a Flood-Control Program

By G. C. Dobson [1]

THERE are in the United States more than 8,400 dams and reservoirs built at a cost of more than 2 billion dollars. This capital investment is depreciating by millions of dollars every year as a result of excessive silting caused by accelerated soil erosion. An estimate has been made,[2] on the basis of 81 reservoir surveys, that 38 percent of existing reservoirs in the United States will have a useful life of 1 to 50

(*Continued on next page*)

[1] Acting head, Section of Sedimentation Studies, Division of Research, Soil Conservation Service, Washington, D. C.

[2] Brown, Carl B. Rates of silting in representative reservoirs throughout the United States. Trans. Amer. Geophys. Union, 18th Ann. Meeting: pp. 554–557 (1937).

be continued under the same practices used during the first stage—this to obtain comparable data on the effects of improved land-use and erosion-control practices upon water conservation, run-off, and flood control for comparatively large areas.

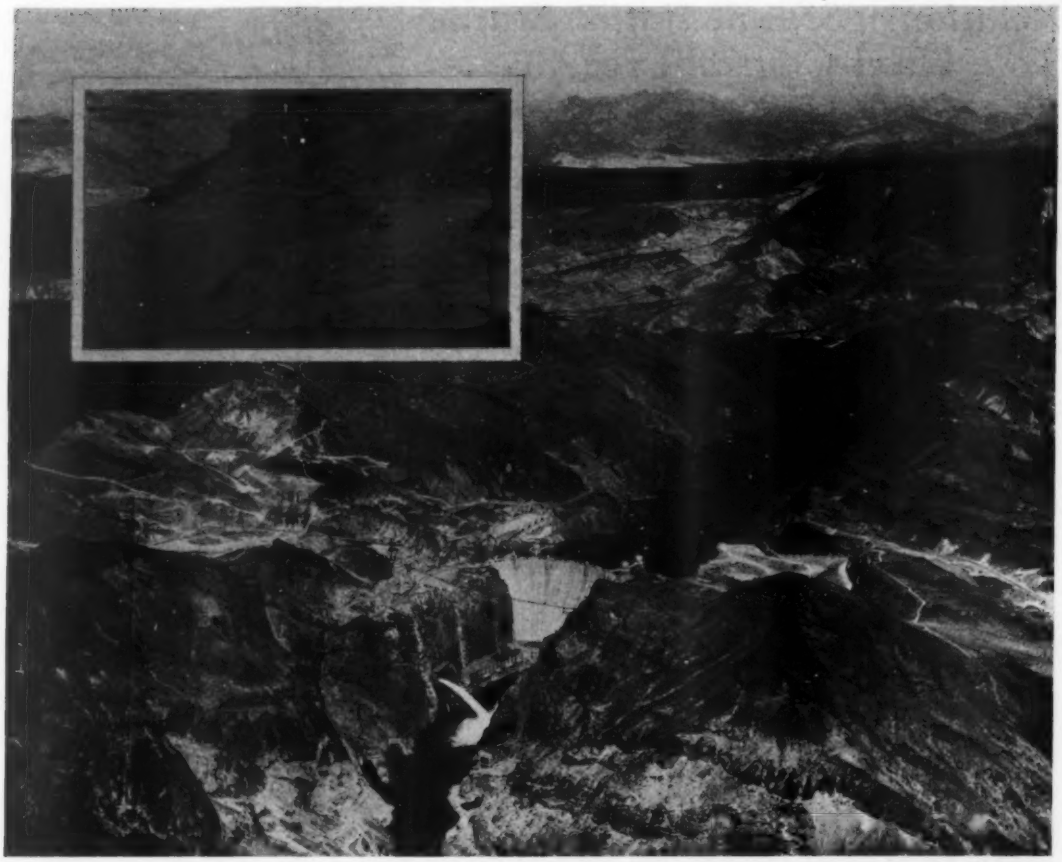
In watersheds ranging in size from about 30 to 5,000 acres, information on rates and amounts of run-off and erosion from rains of different amounts, durations, and intensities will be collected to determine the effect of size of watershed on the rate and amount of run-off. Similar mixed land-use practices and erosion-control measures will be maintained on these watersheds so as to eliminate, as far as possible, any differences in run-off due to these practices.

At the outlets of all the watersheds, gaging stations are being constructed. On the smaller watersheds, the Parshall flume and other types of flume being developed will be installed; and on the larger watersheds, foot bridges and cable stations will be installed, in accordance with specifications of the United States Geological Survey, for making current meter measurements. The Ramser silt sampler will be employed for the measurement of soil losses from small watersheds, and a silt sampler is being developed in the hydraulic laboratory for taking point samples in the larger streams.

Studies will be made of the accumulation of flood flows from small areas, and of the assembly and propagation of flood flows through the larger stream channels, to determine the flow and stage reached as the flood progresses downstream. This is a matter on which factual data are extremely inadequate. The rational solution of the land-use phase of flood problems depends on a thorough knowledge of the hydrology and hydraulics of flood phenomena from rivulets to major streams. Not until the accumulative effects of land use on small areas can be traced through to major flood flows will it be possible to determine quantitatively the influence of various types of land use on flood flows.

In order to extrapolate from the maximum area of 5,000 acres available on the Coshocton project, to areas of greater size within the Muskingum Conservancy District or elsewhere, and to evaluate soil and topographic variations occurring in the North Appalachian area, it is necessary that subwatersheds be developed outside the Coshocton area. A gaging station has already been established on Mill Creek, below its junction with Little Mill Creek (the main stream of the Coshocton watershed) giving an area of about 17,600 acres. This station is operated cooperatively by the Muskingum Conservancy District, the United States Geological Survey, and the Soil Conservation Service. Another area of about 53,000 acres on Salt Creek near Zanesville, Ohio, has been gaged for some time by the Soil Conservation Service. This area gives an extrapolation point above that of the Mill Creek station. Other suitable watersheds will be located within the Muskingum Conservancy District and studies made to secure information of peak flood flows on still larger watersheds.

The possibility of a much wider geographical extension of the results obtained will be investigated through run-off measurements on small plots, using artificial applications of rainfall. This will make possible the immediate collection of data by eliminating the necessity of awaiting the occurrence of the range of rainfall conditions during natural storms. It is anticipated that the relation between the run-off from small plots and that from watershed areas can be reliably established, thus enabling extrapolation of the watershed results throughout the North Appalachian region represented by the study. It is believed that a network of these studies, representing the major hydrologic divisions of the United States, will make possible the determination of the run-off and flood-producing characteristics of watersheds in any region where, in the interests of soil and water conservation and flood control, such information may be desired.



Aerial view of the great Elephant Butte Dam. (Courtesy Reclamation Bureau.) Inset: Silt deposits in Lake Meade near Pierce's Ferry; 12 feet thick, 300 feet wide, 1½ years after completion of the reservoir.

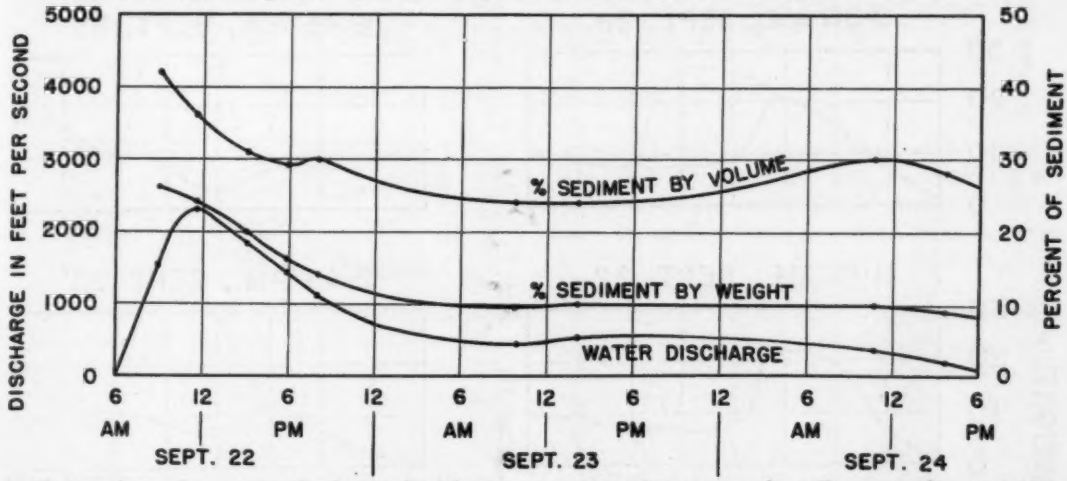
SEDIMENTATION—Continued from page 219

years, 24 percent a life of 50 to 100 years, 21 percent a life of 100 to 200 years, and only 17 percent a life of more than 200 years. Such a situation makes it obvious that a major aim of any watershed conservation program should be the preservation of the effectiveness of these reservoirs and extension of their useful life.

At least one-fifth of all reservoirs in this country, representing probably three-quarters of the total investment, depend solely upon storage for their usefulness. These storage reservoirs, in addition to their various primary functions, exercise an important effect on flood control in the country as a whole; in some watersheds they are a major influence. Flood control through reservoir storage is of prime importance in the Miami and Muskingum watersheds of Ohio, the Trinity and Brazos watersheds of Texas, and is of significance in such watersheds as the Pee Dee and Catawba in the Carolinas where chains of power reservoirs create large storage.

Under the new Nation-wide flood-control program now being developed, the Department of Agriculture is designated as the responsible Federal agency to promote and establish watershed protection designed to supplement downstream flood-control measures developed by the War Department. In this program it seems only natural that one major aim should be the protection of specific downstream flood-control works—reservoirs, leveed areas, channel improvements—against damage by silting. This objective might constitute the keystone of a program which would be distinct from, but parallel with, and using mostly the same practices as, the present program of land treatment designed primarily to preserve agricultural values. In such a program the warranted costs of land treatment might be determined basically

Water discharge and percent of sediment by volume and weight from 3-day flow on Rio Puerco.



by the benefits to downstream flood-control works, or to reduction of flood flows where costly downstream engineering works are not economically justified as in many smaller agricultural valleys. Added to these basic costs, however, would be additional costs justified by benefits to the treated land.

In determining basic costs, this would put the emphasis on downstream or "public" benefits in contrast with the present programs in which they are based largely on private benefits. Land treatment for flood control would be carried out only above downstream flood-control improvements, or above areas subject to appreciable flood damage where engineering works are not feasible. Following such a policy much land might be adequately treated because of downstream benefits which would not justify proper treatment solely from the practical economic standpoint of present agricultural values. This program might run concurrently with, but separate from, the present program based on demonstration areas and conservancy districts located largely to meet agricultural needs and without regard to specific flood-control projects.

It is obvious that an accurate record of damages by silting to existing downstream developments, which affect floods and flood control, is a necessary prerequisite for determining the priority of areas for treatment in any major watershed or for determining the costs of treatment justified in the light of known damages and expected benefits.

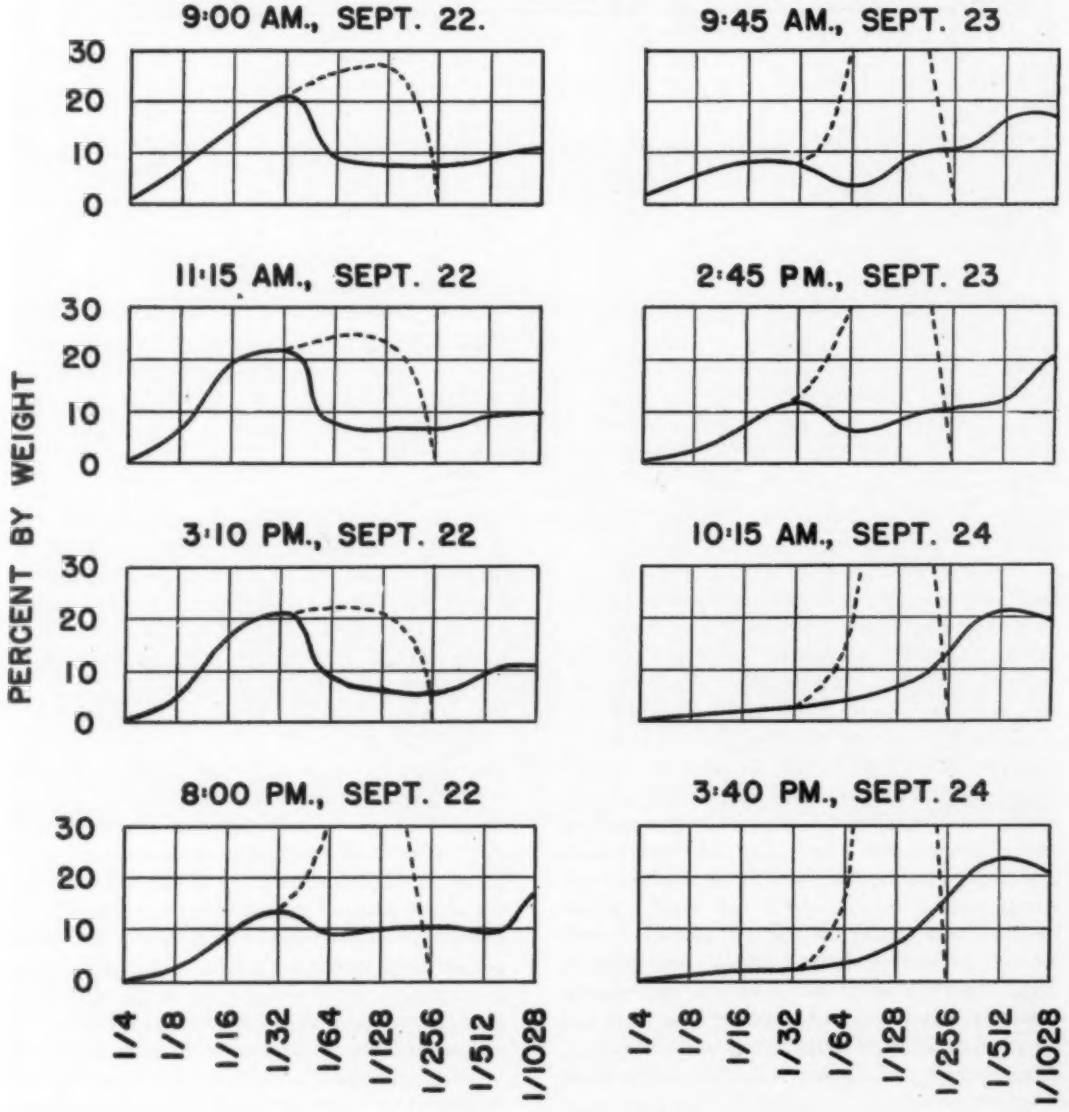
The determination of such damages is one of the principal functions of the Section of Sedimentation Studies. The development of corrective and preventive measures to supplement upland methods of soil conservation is another. For example, corrective measures necessary for full protection of flood-control reservoirs may include stream-bank protection in tributary valleys, storage of erosion debris on waste areas in the alluvial valleys, development of protective vegetative and mechanical treatment around reservoirs to prevent shore-line erosion and screening out and depositing a part of the silt load in the valley just above the reservoir.

Concretely stated, the objectives of sedimentation studies are: (1) To provide accurate information on the damage already done by sedimentation to all downstream resources and developments as well as the magnitude of potential damage to be expected under present conditions and thereby to establish one measure of the relative needs of different watersheds for erosion control and readjustments in land use; (2) to provide more specific knowledge of the natural laws governing the erosion of soil by water; and (3) to develop new and more economical methods of treating and manipulating silt-laden waters to minimize damage to valley agricultural lands and to other developments and resources by control of bank erosion and sedimentation within water courses and on flood plains.

To accomplish these objectives, sedimentation studies are carried on under four separate but interrelated projects which may be described briefly as:

Suspended load samples collected at intervals during 3-day flash flow in Rio Puerco. (Sample on extreme left from Rio Grande above mouth of Rio Puerco.)

Distribution curves of suspended load discharge during 3-day flow on Rio Puerco.



NOTE - DOTTED LINES REPRESENT APPROXIMATE DISTRIBUTION OF SEDIMENT WHEN FLOCCULATED.

(1) Investigations, through field studies and surveys, of reservoir silting as affected by land-use and topographic conditions within the watershed.

(2) Investigations, through field studies, of the sources, quantities, forms, and effects of recent accelerated sedimentation in stream channels and on valley lands, and development of new methods for reducing and eliminating damage by erosion debris through control of bank and channel erosion and

(Continued on p. 234)

Economic Implications of a Soil and Water Conservation Program

By Walter J. Roth [1] *and Alexis N. Garin* [2]

SOIL conservation in contrast to soil misuse may be viewed from the standpoint of the farmer or the public. The farmer may reasonably ask, "How far will it pay me to go in adopting and operating a soil conservation program under my conditions of soil and slope, the degree of erosion on my farm, the limitations of the climate in my area, and the specific market opportunities open?" Similarly, the public may ask, "How far should we contribute to a soil and water conservation program on private land in order to avoid the damages from erosion on lands which cannot of themselves pay for soil conservation? What price ought we pay to obtain the widespread social and economic benefits of soil and water conservation?"

Answers to these questions may be suggested by a specific instance of how a soil and water conservation program works when applied to an individual farm and how the absence of such a program affects the public interest. Inferences may be drawn from studies covering the damages to highways from erosion in one of our Northern States and from studies covering the siltation damages to municipal water-supply reservoirs in one of our Southern States.

Individual Farmer Point of View

The individual farmer's point of view on a specific farm is shown in an economic survey of the farms of the Crooked Creek demonstration area in western Pennsylvania. The total watershed comprises 120,000 acres lying in Indiana and Armstrong Counties within the Allegheny Plateau region, where elevations range from 950 to 1,600 feet. The topography is rolling to steep. Soils derived from sandstones and shale prevail. Their virgin productivity never was high and, being shallow, growing crops are adversely affected by dry weather. Much of the cultivated land is on steep slopes. Because of cultivation on these steep slopes, the shallow, sandy, and shale soils lack humus, and under the heavy Appalachian rains erode severely. The crop land has suffered from erosion, as has the pasture and other land, while in contrast, the wooded land shows little erosion. The pasture and other lands are badly eroded, this being former crop land abandoned because of erosion.

The farming may be classed as general in type. Livestock and livestock products account for approximately three-fourths of the gross farm income. Of the livestock enterprises, dairying and poultry are most important.

From the details of the survey covering farm organization, farm operation, farm income, and related items, it is possible to select a farm typical of the full-time farms in the area, and to project its operation into the future for a period of 5 to 10 years under a continuation of its present soil-depleting system. In contrast, and as a basis for judging the feasibility of the soil-conserving system, the same farm may be reorganized according to the recommended soil- and water-conservation programs and its operation likewise projected into the future for 5 or 10 years. A comparison of the results should furnish an opportunity to compare the economic feasibility of the one versus the other. This has been done and is reported here in tabular form.

The details of the changes involved are shown in the table and need not be restated here. It is sufficient to note that the size of farm remains constant throughout the period while the crop acres are reduced in both cases, particularly under the soil-conserving system. The changes in cropping under the soil-depleting system involve some shifts in acreage and notably some decline in yields. This is a normal consequence of soil misuse. In contrast, the soil-conserving system may correctly be expected to produce increased yields. The yields reported are not excessive; in fact they may be considered very conservative in view of the careful land selection, the crop rotations, the application of lime and fertilizer, and the control of erosion. Another feature of the soil-conserving system is the increase in the permanent pasture and woodland acreage. No woodland in the soil-conserving system is mistreated through grazing, a practice which is continued under the soil-depleting system. Idle land, which increases under the soil-depleting system, is restored under the

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	Present			5 to 10 years hence					
	A. The current system			B. The soil depleting system			C. The soil conserving system		
Size of farm....acres	105			105			105		
Crop land....do	56			54			50		
Permanent pasture....do	23			21			28		
Woods pastured....do	4			4			.....		
Woods not pastured....do	9			9			21		
Farmstead, idle....do	13			17			6		
	Acres	Yield	Production	Acres	Yield	Production	Acres	Yield	Production
Crop production:									
Corn	8.5	34.0	289	7.5	29.0	217.5	9.0	37	333
Oats	8.5	25.0	212.5	7.0	23.0	161	9.0	28	252
Wheat	6.0	12.0	72	6.0	10.0	60	6.0	15	90
Rye	3.5	10.0	35	3.5	9.0	31.5	2.0	12	24
Buckwheat	2.5	23.0	57.5	3.0	21.0	63	1.0	25	25
Potatoes	1.0	100.0	100	1.0	80.0	80	1.5	120	180
Hay, total	19.0	1.0	19	17.0	.9	15.3	21.5	1.3	27.75
Alfalfa	.5	2.0	1	.....	.....	.....	1.5	2.5	3.75
Mixed	14.0	1.0	14	14.0	.9	12.6	16.0	1.2	19.2
Other	4.5	1.0	4.5	3.0	.9	2.7	4.0	1.2	4.8
Pasture	7.0	.....	.....	9.0	.....	.....	.....	.....	.....
Receipts, annual:									
Livestock			$884.00			$738.00			$1,184.00
Crops			97.00			77.00			180.00
Miscellaneous			15.00			15.00			15.00
Total			996.00			830.00			1,379.00
Expenses, annual:									
Fixed charges			421.00			421.00			421.00
Variable expenses			538.00			485.00			721.00
Total			959.00			906.00			1,142.00
Farm income			37.00			−76.00			237.00

opposite system to some use, as woodland or pasture or possibly crops. An improvement in the quality of the pasture and in crop yields is expected.

The net effect of these changes is indicated by receipts, expenses, and farm income under the three systems.

The continued operation of a soil-depleting system is followed by a decline in farm income. Despite a decline in expenses also, the farm income falls below the previous income used as a base. Apparently the soil-depleting system cannot maintain the farm as an income producer. In fact the estimated receipts are actually lower than the amount necessary for estimated expenses, resulting in a negative farm income. In the soil-conserving system, despite a higher total for annual expenses, the earning is higher than the original farm income, and considerably higher than the returns from the soil-depleting system.

No particular changes in labor, power, or equipment are contemplated in the soil-conserving system. In spite of expansion in some crops, the smaller total crop area will not require additional operations expenses. The additional outlays, termed variable expenses, are intended to cover seed, lime, fertilizer, and harvesting charges. Some added livestock costs are also involved, since concentrates are purchased to supplement the additional hay. The extra potatoes are sold and feed grains and hay are fed to the dairy cows and poultry, these two lines of animal husbandry having an available market.

As to the estimate covering maintenance of erosion-control structures and other soil-conservation measures, this figure is low, the assumption being that the only measures necessary are the changed cropping program, some strip cropping, contour operations, and a few inexpensive structures. The latter are built of local materials with local labor and require no large annual cash outlay. The changed cropping includes some change to pasture, some shift to woodland, and the protection of woodland from grazing.

Public Point of View

Under the public aspects of soil conservation are included (1) the effects of public policy affecting soil conservation, i. e., public land policy, credit institutions, land tenure, taxation, research and education, benefit payments, legal phases; and (2) those phases of erosion control which invade more than one land unit and cause direct damage to other individuals and the public.

In a general way nearly everyone now recognizes that soil erosion is a destructive force which touches

the public purse in many ways. If the type of knowledge that is most useful to public commissions in charge of public enterprises affected by erosion, to legislators, and to government officials is to prevail, the indefinite general impressions concerning damages and the costs of correction must be replaced as rapidly as possible by more definite measurements. In this connection brief analyses of cost studies are here presented.

A reconnaissance survey of erosion damages to highways in 16 southwestern counties of Wisconsin, comprising about one-fifth of the State, shows that for each mile of public highway (total of 20,596 miles) at least $42 is spent yearly to repair erosion damages to banks, shoulders, road beds, drainage ditches, bridges, and culverts. Although the data secured during this survey are in many respects inadequate to make a satisfactory appraisal of the total damage caused by erosion and of the methods that are economically desirable to reduce the damage, enough information was secured to indicate that prevention of the more serious damages, at least, is less expensive than their repair.

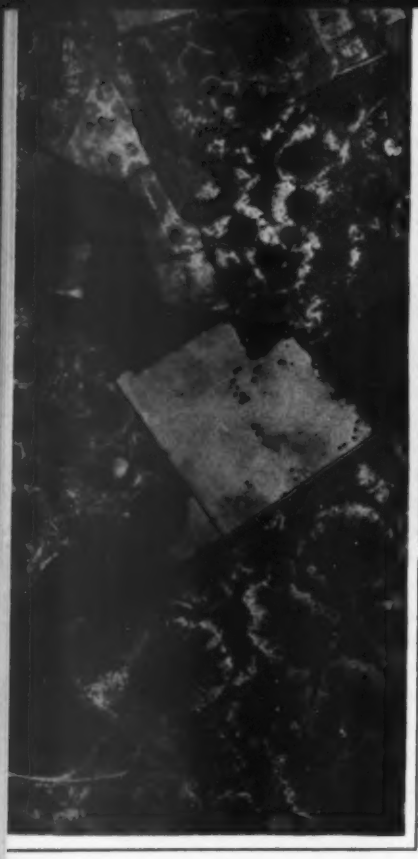
The preliminary results of investigations of public expenditures for municipal water-supply reservoirs and appurtenent developments in North Carolina, made in cooperation with the Research Section of Sedimentation Studies, shows that for Burlington, Greensboro, High Point, and Winston-Salem, the initial investment amounts to a total of $2,655,000 for the present aggregate water-supply sources of these cities. To this original investment must be added interest on bonds. As these cities have financed their water-supply development by issuing 30- to 40-year serial bonds, it can readily be seen that at the end of 40 years when the last bonds will be paid for, assuming that equal amounts are retired each year during the period, the original investment will be approximately doubled at 5 percent interest. This will bring the total investment up to $5,310,000 at the end of 40 years.

The rate of silting of the Greensboro and High Point reservoirs was investigated in 1934 by the Section of Sedimentation Studies and later an estimate was made on the basis of a reconnaissance survey of the rate of filling of the Burlington and Winston-Salem reservoirs. The average rate of silting of the four reservoirs will amount to a loss of 36 percent of the original capacity at the end of 40 years. The annual monetary loss of this depletion is around $48,000, or a total of approximately $2,000,000 at the end of 40 years, using the original investment plus interest as the amount of actual outlay.

The total drainage area of this group of reservoirs is approximately 178,000 acres. According to information on actual sales, opinions of local real-estate dealers, and land-bank appraisers, the average value of an acre would not exceed $40. This gives the total land value of the four watersheds as approximately $7,120,000. Startling as it may seem, the municipal water-supply developments represent an investment of approximately three-fourths of the total land value in the drainage basins in question. In the case of one of the cities, its reservoir cost alone is considerably more than the total land value of its entire watershed.

Because we have no accurate physical data upon which to base an estimate of the probable effectiveness of our soil-erosion control measures in reducing the relative proportion of silt loss to flood run-off, the more exact calculations of this public aspect of soil conservation are somewhat limited. There are, however, in the Deep River area of High Point two first-class stream gaging stations maintained by the United States Geological Survey, and a considerable number of discharge measurements have been made since the Soil Conservation Demonstration Project was established there in 1934. Silt sampling has been carried on since that time during all periods when the amount of suspended matter was appreciable. The results show a 25-percent decrease in the quantity of suspended matter in stream discharge since 1934. This decrease is constant whether based on monthly and yearly averages or on individual storms of approximately the same intensity and duration. The period is too short, however, to reach final conclusions. It should also be borne in mind that only about 45 percent of the land in the watershed is covered by cooperative agreement with the Service.

The cities thus far contacted have expressed a willingness to spend substantial sums for erosion control, provided the entire watersheds are brought under control to ensure certain and tangible protection. With this in view the Service is contemplating a complete cost study of the erosion-control measures applied on the Deep River watershed at High Point and the Horsepen Creek drainage area at Greensboro. It is hoped that we shall then be in a position to answer inquiries from cities concerned with impairment of investments due to silting of reservoirs and the costs of clarification of silty waters for municipal use. Further, as a major objective, the Service expects to work out an adequate factual basis for effective cooperation in controlling erosion in tributary watershed areas, including public highways which contribute to the aggregate erosion problem.



Recent Achievements of the Section of Climatic and Physiographic Research

By C. W. Thornthwaite[1]

Above: Mass movement of the soil beneath the vegetal cover is an important process in shaping the slopes of humid lands. The flowage and slumping on this Ohio hillside involved about one-half acre of land and occurred after heavy rains.

Left: In limestone lands having subsurface drainage erosion exhibits peculiar features such as the circular scars in this aerial view in Meade County, Ky. Such areas demand special methods to control erosion.

IN THE April 1937 issue of SOIL CONSERVATION the research program of the Section of Climatic and Physiographic Research was outlined briefly.[2] At that time it was pointed out that the work of the section was limited to observational and library studies, phases of research rarely encountered in the Department of Agriculture, but which are of especial value in amplifying and supplementing controlled experimentation by providing an historical perspective and supplying means for extrapolating the results of experimentation beyond the limits of the area in which the experiments are conducted.

The objectives of the Erosion History Unit are to assemble the results of past experience of practical farmers in controlling erosion, to determine the types of land-use practices which were responsible for the incidence and spread of erosion, and to collect information on the development of erosion-control practices in foreign countries having climates and erosion problems similar to our own.

Since erosion is a geologic process, it is the function of the Physiographic Unit to determine the influence of rock type, structure, and the slope and exposure of the land, on the forms of erosion which develop and the physiographic processes involved.

Since these processes vary with climatic conditions, the Climatic Unit has undertaken the work of delimiting climatic regions within which erosion and erosion-control practices would be similar, determining the effect of various types of rainstorms on erosion through the life history analyses of storms, developing improved methods of determining the expected frequency of rains of high intensity, and contributing to our knowledge of the relation of rainfall to run-off and the influence of land-use practices on run-off. The Ecology Unit has as its objective the determination of the relationships between plant succession and erosion control and stabilization.

During the interval since the summary statement of the research program was published, considerable progress has been made along several lines.

Climatic Research

The climatic research station established in western Oklahoma in 1935 continued in operation until July 1, 1937, when it was discontinued because of insuffi-

[1] Head, Section of Climatic and Physiographic Research, Division of Research, Soil Conservation Service, Washington, D. C.

[2] C. W. Thornthwaite: The Research program of the section of climatic and physiographic research, SOIL CONSERVATION 2:218–220, 236. 1937.

cient funds. During the year-and-a-half of operation a large amount of information on the history of rainstorms was collected. This paved the way for the establishment of a similar but considerably larger climatic research station in Ohio as a State W. P. A. project, with the Muskingum Watershed Conservancy District cooperating. In this project, covering 8,000 square miles of the Muskingum Valley, 500 self-recording rain gages and an equal number of instruments for measuring temperature, relative humidity, and wind velocity and direction were installed at intervals of approximately 4 miles. The construction stage of this project commenced in April, and reliable data were being obtained by the 1st of June. Maps showing the distribution of surface temperature for each hour of the day were made commencing with that date. Precipitation maps showing the distribution and intensity of rain for half-hour intervals were made for the period beginning July 1. For a continuously rainy day, 48 of these maps must be made. It required 667 maps to represent the rainfall for the month of July, and 2,258 maps for the period from July 1 to November 1. As in the Oklahoma research project, maps are made for temperature, relative humidity, wind velocity and direction, and cloudiness for each hour.[3]

During the period of operation of the Oklahoma climatic research station, and the period of construction in the Ohio station, noteworthy progress has been made in the development of improved inexpensive instruments. A self-recording rain gage, which has proved adequate in all respects, was developed and has been manufactured at a price only approximately 25 percent of the previous price. Nearly 2,000 of these automatic rain gages have been put into service in the United States during 1937. Similarly, a new anemometer and wind vane were designed and manufactured at only a fraction of the cost of any satisfactory previous instrument. Similar economies were effected in the design of instrument shelters and wind towers. An accessory to the recording rain gage, which gives on the rain gage chart a continuous record of wind velocity and direction as well as precipitation, has been developed. The complete assembly for giving a continuous automatic record of precipitation and wind velocity and direction can be obtained for approximately one hundred dollars when purchased in quantities. An evaporation pan giving a continuous record of evaporation is the most recent development at the Ohio project, where a sample instrument is now on test.

[3] Leonard B. Corwin: Sampling the weather at the Oklahoma climatic research center. Soil Conservation 2: 237–238, 244, illus. 1937.

The material obtained at the Oklahoma and Ohio centers has proved indispensable in the study of rainstorm morphology. It makes possible the determination of the frequency of rainfall of specified intensities and amounts at individual stations and also of storms of specified size and duration over entire watersheds. This information also aids in determining the meteorological conditions which produce rains. It is hoped that it may be possible through this study to determine the combination of meteorological conditions which would produce the maximum storm and thus to determine the size and extent of this limiting storm.

The climatic data being recorded on the Muskingum in Ohio are especially significant because of the stream-gage measurements being made on a large number of the intermediate and smaller tributaries by the United States Geological Survey and the Muskingum Watershed Conservancy District, and because of the location of the Land-Use Hydrology Watershed project of the section of Watershed and Hydrologic Studies of the Division of Research. The unparalleled rainfall record

Detailed studies were made of representative examples of the deep caving gullies of the southern Piedmont. Measurements of erosion were made from iron rods driven deep into the gully heads and walls.

being obtained through the operation of the close network of self-recording rain gages and the determination of run-off from the several watersheds of the valley has permitted the study of the relation between rainfall and run-off on an entirely new basis. It is believed that this study of rainfall-run-off relations will make possible the determination of the effect of land use on floods. The climatic information being obtained makes it possible to treat each rainstorm as an individual event, and permits the isolation of the various influences which produce variations in the rainfall-run-off relationships.

A recent bulletin, "Sources of Moisture for Precipitation in the United States",[4] by Benjamin Holzman of the staff of the Climatic and Physiographic Research Section, forms an important contribution to the literature of climatology. In it the author demonstrates the intimate relation between modern air-mass meteorology and hydrology. He presents a revised concept of the hydrologic cycle. Implications of this study have been presented in a previous article [5] in this magazine.

Of immediate practical value is research on precipitation intensity frequency conducted by Katharine Clarke-Hafstad. It is recognized that engineers in designing erosion and flood-control structures require a measure of the frequency of rains of specified intensity and amount. The two most valuable methods for determining rainfall intensity frequency are the so-called station-year method, employed by the engineering staff of the Miami Conservancy District,[6] and the Yarnell [7] method. It has been pointed out previously that both methods yield inadequate results.[8] The present spacing of stations makes it impossible to record all the intense storms that cover small areas, and causes the too-frequent sampling of storms of lower intensity that cover large areas. The station-year method combines records of various lengths from several stations to obtain an aggregate station-year record. This aggregate record has been assumed to represent a long period record for a single station. Because of the too-frequent sampling of storms of lower intensities it has been shown that only a part of the aggregate station-year record can be said to be valid.

The method employed for testing the amount of duplication in the rainfall records is based on a statistical technique used in testing persistence in observations taken at equal time intervals. It is possible by this technique to determine which combination of stations and years yields the most information on the frequency and intensity of rainstorms.

In determining rainfall intensity frequency Yarnell employed only the records from the automatic rain gages at the 211 first-order Weather Bureau stations scattered over the entire United States. The analysis of the voluminous rainfall records from the 500 gages in operation in the Muskingum Valley, now in progress, should give some idea of the size and number of storms missed in the Weather Bureau station network, which will in turn permit a revision of Yarnell's values for storms of short duration and high intensity.

Physiographic Research

General unfamiliarity of agricultural research workers with geological processes affecting land forms calls for special consideration. On this account, the first publication of the unit, "What is Soil Erosion?" [9] examines erosion from the standpoint of the geologist or physiographer, and attempts to show the relation of what is popularly called "geological erosion" to soil erosion. With the aid of many illustrations it describes the various physiographic processes involved in soil wastage, indicates in nontechnical language some of the regional variations in these processes, and the climatic and geologic basis for such variations.

In order to stress the relation of physiography to soil erosion the first research projects were designed to study a variety of physiographic processes in widely contrasting regions. A manuscript on soil erosion in the limestone lands, submitted for publication by Samuel N. Dicken and H. Bates Brown, Jr.,[10] in September 1937, deals with the peculiarities of soil erosion in regions where the drainage is subterranean. In the United States there are more than 5,000,000 acres of agricultural land in which channels have been dissolved in the soluble limestone, and on which surface drainage is partially or entirely lacking. As a result of the absence of surface drainage, soil erosion exhibits peculiar characteristics, and methods of erosion control successful elsewhere cannot be applied.

A second technical study, dealing with principles of gully formation in the Piedmont, by H. A. Ireland, C. F. S. Sharpe, and D. Hoye Eargle [11] was submitted for publication in December. Because of the deep

[4] Benjamin Holzman: Sources of moisture for precipitation in the United States. U. S. Department of Agriculture, Tech. Bull. No. 589, 41 pp., illus. (October 1937).

[5] C. W. Thornthwaite: The hydrologic cycle re-examined. p. 85, October 1937, Soil Conservation.

[6] Engineering Staff, Miami Conservancy District: Storm rainfall of Eastern United States (revised). Technical Reports, pt. V. 352 pp., illus., 1936.

[7] David L. Yarnell: Rainfall intensity-frequency data. U. S. Department of Agriculture Misc. Pub. No. 204, 67 pp., August 1935.

[8] C. W. Thornthwaite: The reliability of rainfall intensity-frequency determinations. Trans. Amer. Geophys. Union, pp. 476–488, illus. 1937.

[9] C. F. S. Sharpe: What is soil erosion? U. S. Department of Agriculture Misc. Pub. No. 286. (In press.)

[10] Samuel N. Dicken and H. Bates Brown, Jr.: Soil erosion in the limestone lands of western Kentucky. (In manuscript.)

[11] H. A. Ireland, C. F. S. Sharpe, and D. Hoye Eargle: Principles of gully erosion in the Piedmont of South Carolina. (In manuscript.)

weathering of the bedrock in the southern Piedmont, gullies cut rapidly to great size and present a difficult problem in erosion control. Field studies demonstrate the relation of the deep, caving gullies to specific rock and soil types and land-use practices. Detailed observations on representative gullies show the processes by which they are formed, and the close correlation of these processes to climate and vegetation. Caving of the gully head and walls, and clearing out of the channel, the principal elements in the process of gully formation, are found to be dependent on rainstorm types, and the annual cycle in these processes is controlled by seasonal changes in the climatic forces. In knowledge of the areas of inherent vulnerability, of the processes active, and of seasons of special hazard we are close to the root of the gully-erosion problem. These are the basic data on which erosion-control techniques particularly adapted to the Piedmont must be planned.

Recent field studies have suggested that the natural erosion in humid lands was not only less in amount but was also of different type from the present culturally-induced erosion. It is apparent that under natural conditions where the soil surface was almost completely covered with vegetation and with the organic products of plant life, gullying was practically nonexistent and sheet wash was so slow as not to interfere with soil-forming processes. Thus, there is the suspicion that most of the denudation was due to mass movement—slow, downhill soil creep, earth flow, and slumping. The evidence of this form of denudation is usually less conspicuous than the evidence of gullying and sheet wash. For this reason there is a tendency to minimize its relative importance. Field studies of mass movement to identify its various forms, and to determine their significance and areal distribution, are under way.

Erosion History

At the beginning of 1937 a bulletin entitled "Early Erosion-Control Practices in Virginia," by A. R. Hall,[12] was published by the Department. Virginia was one of the earliest agricultural areas in the United States and Hall's purpose was to indicate the importance of soil erosion in the area from the beginning of settlement. A second manuscript, "Erosion and Its Control in Oklahoma Territory", by Angus McDonald,[13] is now in press. Oklahoma Territory was the last large agricultural area to be occupied, and in this manuscript McDonald shows how much damage was done to the land in the short span of 20 years, and describes the methods which farmers developed in attempting to prevent or control soil erosion.

Erosion history research projects are now in operation in seven States. Each project consists of one trained supervisor and 20 or more relief workers. On the basis of early experience, a uniform system has been developed for examining early records and transcribing verbatim those items dealing with erosion and floods, control measures employed, and the related land-use practices. The information secured will serve as source material for future publications.

An aspect of erosion history research which should give perspective to our present erosion-control activity is the study of the history of erosion and its control in the ancient world and in foreign countries in our own day. These fields of research are now in progress under the direction of Lois Olson and it is expected that within the coming year two papers will be forthcoming—one dealing with erosion in the ancient world and the other with the contemporary experiences in foreign countries. The straight furrow, so prized by our present day American farmers, has been traced to Cyrus of Persia, in the fifth century, B. C., and contour cultivation now being advocated was described by Pliny the Elder in the first century, A. D. Dry land farming is found to have been a common practice among the Romans.

Ecologic Research

Despite the recognized importance of vegetative cover in erosion control and the urgent need for the determination of principles of plant succession on eroded areas, a comprehensive program of ecologic research, although formulated, awaits further development. A certain amount of work incidental to research discussed above has been done, but it is not focused on the problems involved in the use of vegetation in erosion control.

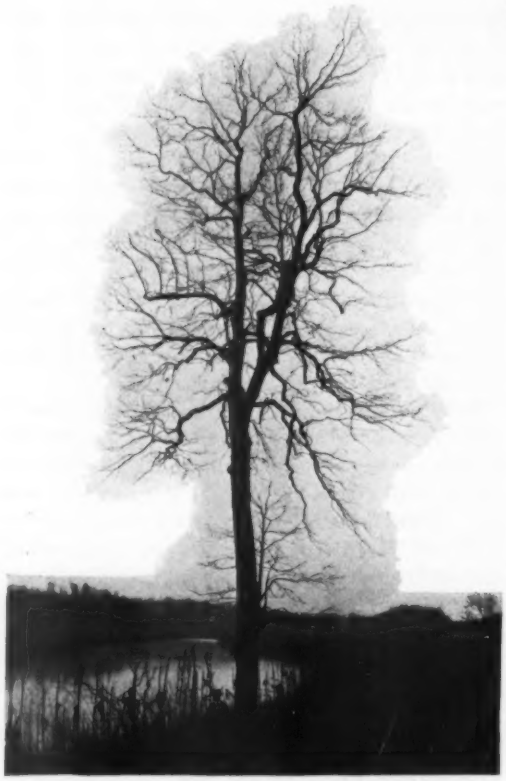
As has been pointed out previously, the various lines of investigation in the section of Climatic and Physiographic Research must be conducted as a single integrated unit. Each advance in one line aids in interpretation and stimulates further advance along another line. For example, rainstorm analysis suggests a new approach to the study of physiographic processes of erosion and supplies a new interpretation of erosion processes and forms. The history of erosion supplies a basis for evaluating the effect of erosion on the magnitude of floods.

[12] A. R. Hall: Early erosion-control practices in Virginia. U. S. Department of Agriculture Misc. Pub. No. 256, 31 pp., illus., 1937.

[13] Angus H. McDonald: Erosion and its control in Oklahoma Territory. U. S. Department of Agriculture Misc. Pub. No. 301. (In press.)

The Soil-Saving Persimmon

By S. B. Detwiler [1]



A persimmon tree in North Carolina. (Courtesy Forest Service.)

THE NATIVE persimmon is one of those long-neglected wild plants offering outstanding promise for profitable development under hillculture principles. It is likewise an erosion-control plant of the multiple-use type urgently needed in developing practicable methods for sound and permanent agricultural use of sloping lands.

The area in which the common persimmon is native or will thrive when planted lies south and east of a line from Boston to Columbus, Des Moines, and San Antonio. This territory of approximately 900,000 square miles contains more severely eroded hilly farm land than any other portion of the United States. Excluding the higher elevations and other areas not adapted to this species, it is safe to estimate that the persimmon is today naturally distributed over an area of not less than 500,000 square miles.

The function of hillculture research is to secure cooperative action in finding and improving erosion-resisting plants having superior economic qualities for general use in soil defense. One phase of this work relates to the methodology of land organization and the application of ecological principles in managing perennial plant covers for the safe use of steep lands in producing profitable crops furnishing annual returns to the farmer. The persimmon has high intrinsic value for these purposes.

Recent discovery of a new and deadly wilt-disease, which may destroy the future usefulness of the persimmon if it is not checked, is news of major importance to all soil conservationists. This disease was first found in 1937, and the oldest known infections date back only 7 years (possibly only 4 years). It is caused by an undetermined species of *Cephalosporium* and has infected trees in approximately half of the persimmon stands growing in an area of some 1,500 square miles lying southeast of Nashville, Tenn. Hence, it is timely to evaluate the merits of this tree. What, then, is the actual value of the persimmon on the 500,000 square miles of its distribution today, and what might it become if preserved and improved for soil-saving farming purposes? The answer is best given by quoting what some leading authorities on this subject have to say about the importance of the tree.

Dr. H. H. Bennett has long and closely studied soil-erosion conditions throughout the region of the persimmon. He is a keen observer of erosion-control vegetation and is preeminently qualified to speak on persimmon in relation to erosion control. Under date of December 17, 1937, in a memorandum to the writer, Dr. Bennett states the case forcefully. He writes:

> Since I talked with you a few days ago about the recently discovered persimmon disease, I have been thinking further along the line of the value of the persimmon tree in connection with our national combat against erosion.
>
> My observations have been that persimmon is one of the first plants to take hold of abandoned eroded areas over an enormous area lying roughly south of the Potomac and Ohio Rivers and the northern part of the Ozarks. Not only has this plant come in voluntarily over many thousands of acres of land thrown out of cultivation because of excessive erosion, but it comes in, in many instances, in thick growth such as causes the development of a layer of leaf litter which has considerable effectiveness in slowing down erosion. In many of these areas erosion has been completely arrested through the voluntary activities of this tree. I have further noted that the roots are long and are difficult to kill. In south-central North Carolina, my experience in cultivating the land where persimmons have previously taken hold has been that sprouts continue to come back almost regardless of the breaking up of the roots with plowing and hoeing of cotton and corn. Accordingly, it seems to me that the root system of the persimmon adds to the effectiveness of this plant in holding soil against erosion.
>
> Because of the high carbohydrate content of the persimmon and the readiness with which it is eaten by livestock, I have thought

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since the beginning of our hillculture studies that this tree should be given a great deal of attention in connection with our plantings on the 18 or 20 percent of land now cultivated which should be retired from cultivation to permanent protective cover of grass, trees, and shrubs. We have a great many varieties or strains of persimmon, which I believe you should consider in a very serious way in your hillculture tests.

This disease threat that you told me about concerns me a great deal. If there is any contribution that this organization can make in any cooperative way to combat the disease in its infancy, it seems to me it is our duty to let those of the Department who are primarily concerned know that we stand ready to help. I wish you would bring these matters to the attention of those of the Department who may be most interested in the matter.

Brief discussion of the Japanese persimmon is in order because it illustrates the economic value of persimmons in general and also because the new disease, if not checked, may attack the introduced species. Knowles A. Ryerson, in California Station Bulletin No. 416 on Culture of the Oriental Persimmon in California, says:

Until recently the persimmon has been grown primarily as a side line, but from present indications in the near future its culture will be an important industry in certain parts of California.

The persimmon has long been the most widely used staple fruit of the Orient. Both fresh and dried, it fills an important place in the diet of China and Japan and has been referred to as "the apple of the Orient" as indicative of its importance there.

The area in the Southern States which can be devoted to persimmon growing is large, and as the public becomes increasingly familiar with the uses of the fruit, it is reasonable to expect that there may again be a marked increase in acreage in that region.

John W. Hershey, tree crop specialist of the T.V. A., in Tree Crops and Their Part in the Tennessee Valley, says of the persimmon:

This fruit shows evidence of being one of the leading "tree crops" of the future. Unlike our orchard fruits, it has few pests, is high in food value and has a good flavor. When dried it tastes somewhat like the fig, but is more easily digested. It grows everywhere and anywhere, even on the poorest soils in the Valley whether or not the farmer desires it. Pigs, sheep, hogs, cattle and wildlife thrive well on this fruit.

The importance of persimmon in development of hill-culture farming is most effectively summarized by Dr. J. Russell Smith, of Columbia University, in his vitally important, very practical, and easy to read book, Tree Crops. Dr. Smith has devoted 40 years of intensive study to evaluation and demonstration of the possibilities of tree crops. In explaining the purpose of his book, Dr. Smith says:

This book is primarily an attack upon the gully. To succeed in this we must have millions of acres of tree crops replacing the destructive plow crops . . . Once we get a cow-feed tree crop established we have a guaranteed outlet, and 20 or 30 millions of acres will not glut the market.

The use of persimmon wood is stated as follows in U. S. D. A. Bulletin No. 1436, Utilization of Dogwood and Persimmon:

The woods of flowering or eastern dogwood (*Cornus florida*) and persimmon (*Diospyros virginiana*) are important in American industry not because of the quantity consumed but because of the unusual combination of properties which fits them for special uses. Other woods have some of the same properties, such as hardness, toughness, fineness of texture, and smoothness when subjected to wear, but few if any possess them all to such a degree as dogwood and persimmon. This combination of properties is of special value for shuttles, bobbins, spool heads, golf club heads, infants' shoe lasts, small handles, brush backs, turnpins, mallets, pulleys, and many novelties.

Of the 8,000 cords of persimmon consumed for dimension stock in 1923, 6,650 cords, or 83 percent, was used in the manufacture of 2,600,000 shuttle blocks, and 17 percent, or 1,350 cords, for golf club heads and shoe lasts.

For people who think in terms of dollars and cents, we may venture to estimate the present cash value of the native persimmon in the United States. Assuming that the forage value of this carbohydrate-rich fruit for farm livestock and wildlife is worth several times the value of the fruit for human consumption, and that the industrial value of the wood and fruit are of present minor importance, but that the soil-conserving benefits of persimmon roots and litter are of high value, it seems reasonable to believe that the present growth of the persimmon is worth at least 5 cents per acre annually on the average acre throughout the half million square miles where it is now well distributed. On this basis, the persimmon returns $16,000,000 in value each year to the people of the United States. If this figure is capitalized at 4 percent the persimmon represents a present capital of $400,000,000. These figures can only be a guess, but the facts and views presented herewith indicate them to be conservative. The rational basis for justifying a strong effort to save the persimmon should be based on the need for superior selections of this tree and similar economic erosion control species in developing a permanent agriculture. The history of epidemic plant diseases makes it clear that they are a continual potential threat against all of our beneficial plant life, without which man cannot live.

Diospyros virginiana; fruit, yellow-orange. A specimen from Louisiana.

Preliminary Notes on Reservoir Studies in the Great Plains States

By Mark P. Connaughton [1]

DURING the past summer, the Section of Sedimentation Studies of the Division of Research completed 10 reservoir sedimentation surveys in the Northern Great Plains States. For the convenience of the reader, a partial summary of data collected in the studies based on these surveys is here shown in tabular form. The surveys were undertaken primarily to measure rates of sedimentation and to establish a means for future correlation of soil losses and rates of run-off from representative watersheds with factors of climate, soils, slopes, and land use. Detailed conservation surveys of the various watersheds will be necessary before the main factors involved in sedimentation can be isolated and their relative importance correctly determined. However, a general analysis based on reconnaissance will be given in the advance reports of the 10 individual studies which are now in preparation.

Enormous gully head developed in loess in the watershed of Wellfleet Lake, Lincoln County, Nebr.

Eroding banks of loess. This lake has lost 10.6 percent of its capacity in 5 years and 7 months because of silting due to soil erosion in its watershed.

Only a brief résumé of some of the pertinent regional characteristics is offered here. As a basis for comparison, the most usable figure in the table is believed to be the annual sediment accumulation per unit of watershed, since this value represents effectively the "rate of sedimentation." The conditions governing this "rate of sedimentation" constitute a combination of the maze of factors affecting run-off and erosion, plus the additional factors of (1) upstream deposition and (2) by-passing of erosional debris entirely through the reservoir during high water stages. These latter factors govern the proportion of total soil washed from the land to that deposited in the reservoir. In effect then, the volumes of sediment listed in the table represent the volume of erosional debris from the

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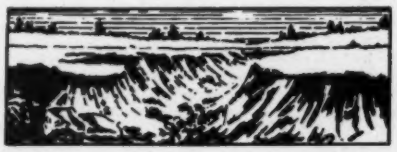
Summary of Data on Reservoir Sedimentation in the Great Plains States

Name and location of reservoir	Age	Annual precipitation during life of reservoir	Watershed area	Original storage capacity	Storage capacity per square mile of watershed	Total volume of sediment	Annual loss of storage capacity	Annual sediment accumulation per acre of watershed
	Years	*Inches*	*Square miles*	*Acre-feet*	*Acre-feet*	*Acre-feet*	*Percent*	*Cubic feet*
Hurley, Potter County, S. Dak.	4.5	10.35	70.0	1,226	17.51	37	0.67	7.97
Wellfleet, Lincoln County, Nebr.	5.6	16.91	43.7	519	11.88	55	1.89	13.26
Hayes, Stanley County, S. Dak.	4.2	10.87	40.0	629	15.73	49	1.86	19.91
Santa Fe, Butler County, Kans.	8.6	27.66	40.0	1,741	43.53	146	.98	28.93
Ottawa County, Ottawa County, Kans.	8.0	20.51	20.5	1,001	48.83	71	.89	29.48
Meade County, Meade County, Kans.	8.8	17.74	18.0	891	49.50	72	.91	31.01
Eldorado, Butler County, Kans.	8.8	29.82	33.0	3,213	97.36	131	.46	30.73
Olathe, Johnson County, Kans.	5.1	31.08	7.0	532	76.00	55	2.03	105.01
Baker, Fallon County, Mont.	29.1	14.07	5.18	756	145.95	254	1.15	114.32
Mission, Brown County, Kans.	13.0	32.05	11.4	1,852	162.46	289	1.20	132.72

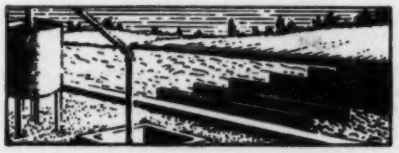


watershed minus (1) the volume involved in upstream deposition and (2) the volume lost by bypassing as suspended load. Obviously, therefore, the rate of sedimentation shown is merely a minimum rate of soil loss from the watershed.

Reservoirs with a relatively small storage capacity per unit area of watershed, such as Lake Hurley and Wellfleet Lake, have a small capacity-inflow ratio and, as a result, flood flows pass through them with appreciable current. Consequently, only a fraction of the finer-grained erosional debris may be deposited, the rest being bypassed as suspended load. In a reservoir having a large capacity per unit area of watershed, a larger proportion of the incoming silt load will be deposited; in other words, the rate of sedimentation will ordinarily represent more closely the rate of erosion in the drainage area.

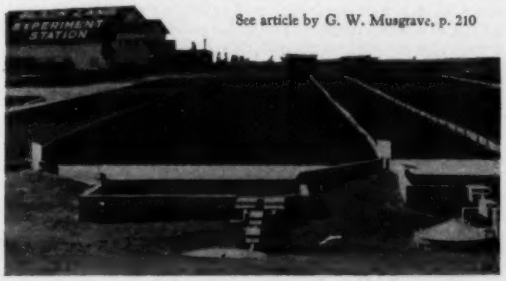
It is evident that the rate of sedimentation will not equal the rate of net watershed erosion unless the reservoir is capable of storing all the run-off from its watershed until complete desilting takes place. Such a condition is rarely achieved in reservoirs, the sole exception being some basins designed for irrigation or conservation storage. In contrast with other sections of the country, the average reservoir in this region is subjected to extensive fluctuation in water level because of prevailing climatic conditions, and stream flow is generally intermittent. It follows therefore that these reservoirs will tend to trap all the sediment during low run-off when no water passes the spillway, and bypass sediment only during periods of abnormally heavy flood flows. However, since reservoirs in the Great Plains States apparently accumulate an unduly large proportion of their total sediment during the irregular and infrequent periods of heavy run-off (Hayes Lake, for example, trapped 33 percent of its total sediment during one 48-hour flood flow), the reservoirs of the region do not have characteristic sedimentation rates dependent on total precipitation. The general correlation between the ages of the reservoirs and the rates of sedimentation, indicated in the table, may be a reflection of the number of these local intense rainfalls which have occurred in the individual watersheds during the life of the reservoir.

The other important factor, namely, the wide variation in extent of upstream deposition in individual watersheds, cannot be discussed here because of limited space. While the data would seem to indicate a tendency for the rate of sedimentation to vary inversely with size of drainage area, this relationship is not consistent, being influenced by the percentage of flat or gently sloping land in the watershed which is subject to sediment accumulation. Reconnaissance has indicated, however, that the average large watershed in this region includes a larger percentage of land subject to upstream deposition than does a small watershed.



Field research laboratory serving as a center of soil conservations investigations in the black land problem area in Texas.

See article by G. W. Musgrave, p. 210



BOOK REVIEWS AND ABSTRACTS

By Phoebe O'Neall Faris

GROUND WATER. By C. F. Tolman. New York and London. 1937.

The author of this new and extensive book, who is professor of economic geology at Stanford University, has given us the first general treatise in the English language on the occurrence, motions, and activities of subsurface water, and the hydrologic properties of water-bearing materials. The text correlates scientific data from many sources, and summarizes the results of intensive studies of subsurface water in the western part of the United States. It is apparent to the reader that in writing the book Professor Tolman had in mind the need for water conservation to meet the periodic deficiency in water supply in semiarid regions and also the occasional severe droughts where rainfall and surface water are normally adequate. Most of the text deals with ground water in granular formations (alluvial and sedimentary deposits), tributary water in the atmosphere and on the ground surface, and water in the unsaturated zone above the water table. Water in superficial fractures and in the large openings in lavas and in soluble rocks is treated also as of importance in certain regions. Two chapters are devoted to the soil and the zone of aeration as background for the study of factors controlling influent seepage from rainfall and from streams, and water spreading to recharge ground-water reservoirs. The works of O. E. Meinzer on ground-water hydrology are quoted extensively.

Introductory to the detailed technical discussions to follow, Professor Tolman gives, in the first and second chapters, an historical account of the development of the ground-water theory and a résumé of the elements of ground-water hydrology. The latter includes discussions of states and origins of water, ground-water composition, natural reservoirs, the hydrologic cycle, the ground-water equation, geologic control of ground water, the zones of suspended water and saturation, movements of water in the zone of aeration and underground, wetting of clayey material with reference to slides and earth-fill dams, and free and confined water.

Rainfall and run-off are treated briefly but adequately to show the importance of meteorological data in determining stream run-off and stream flow. Methods of estimating evaporation and transpiration losses are illustrated by a description of investigations in Owens Valley, Calif., Escalante Valley, Utah, and in the Pomperaug Basin in Connecticut.

Meinzer's discussion of openings in rocks and the types of pore space which hold water is incorporated under the heading "Hydrologic Properties of Water-Bearing Materials, Except Soil," and this is followed up by detailed treatment of openings and the agencies that produce and destroy them, with a summary of Graton and Fraser's exhaustive treatise on the geometry of aggregates of spheres.

The soil is treated in a separate chapter and from the viewpoint of the ground-water scientist; i. e., "the root zone properly delimits the soil zone because the vertical perviousness produced by roots [and cracks and animal and insect burrowings] is one of the important hydrologic characteristics of the soil zone." Soil horizons are discussed briefly, as are seepage and percolation rates in soils, composition of soils, and classifications according to chemical environments, stages of formation, age, principal geologic processes active during formation, and mechanical analysis. The present scheme of classification of soil materials according to particle size as determined by mechanical analysis, by R. E. Davis and H. H. Bennett, is given as is also the equilateral triangle diagram devised by these two authors for indicating the physical composition of soils in connection with field mapping.

Capillary action is treated at some length under the chapter heading "Zone of Aeration." Included are some interesting charts showing the attractions acting on molecules at the surface of a liquid and on those at depth, movement of water in the capillary fringe, and rate and extent of capillary rise.

In a study of influent seepage, including water spreading to recharge ground water reservoirs, methods are described for investigating the continuity of pervious material from surface to water table by use of soil columns and lysimeters and tunnels; while measurement of influent seepage from streams is illustrated by investigations in the Mokelumne and Mimbres River valleys. Several methods of water spreading are described—check dams and other stream-bed improvements, ditches, the basin method.

Percolation and permeability are dealt with chiefly from the point of view of laboratory methods for measurement of velocity and flow in various materials and gradients. Darcy's law governing the relation between velocity of percolation, permeability of water-bearing materials, and water-table slope of free water or hydraulic gradient of confined water, is presented and discussed in some detail particularly in comparison with other formulae. Various permeameters are described, together with field methods for determining permeability and effective velocity.

The water table as occurring in granular material, and in fractures and solution openings, is treated separately because "the . . . 'laws' deduced for ground-water movements in granular materials are not of general application to water in fractures or in large tubular openings." Under the former the author explains the importance of the water table in ground-water investigations, and explains Darcy's law as combined with Meinzer's permeability coefficient for interpretation of water-table gradients. The development of water-table profiles and the effect of surface topography, varying permeability, and the impervious basement upon water-table gradients are treated introductory to the subjects of water-table maps and methods, electrical and geophysical, of locating the water table and bedrock. The section on electrical methods is contributed by J. J. Jakosky, and that on geophysical methods by C. A. Heiland. In the latter, the geologic-geophysical classification of ground water and of geophysical location methods is explained in concise terms and in detail.

Ground water in fractures and solution openings is discussed in a separate chapter as of importance locally and the chapter includes an interesting account of limestone beds—impervious flat-lying, impervious inclined, and porus.

The remainder of the volume is devoted to chapters on confined water, the geological classification of artesian aquifers, wells, oil field fluids, springs, the ground-water inventory, and ground-water provinces of the United States and the Hawaiian Islands. The unusually extensive references included throughout and the glossary of terms are distinctly helpful to the student in his reading of this general treatise.

RELATION OF SEDIMENTATION STUDIES

(*Continued from p. 222*)

sedimentation within the valleys.

(3) Investigations at field stations of the total sediment loads carried by natural streams; correlation of the different phases of these loads with the hydraulic functions of the streams and with the land use and topography of the watershed; establishment of empirical methods for the determination of the bed load carried by any stream; and studies of engineering methods for the control of the movement of sediment within a stream.

(4) Laboratory investigations of principles governing entrainment, transportation, and deposition of erosion debris by flowing water; the development of instruments for use in soil conservation investigations; and the solution, under laboratory controlled conditions, of problems originating in the field investigations.

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